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Operation

HARDTACK

April - October 1958

Project 8.3

GROWTH OF FIREBALL RADII AT VERY HIGH ALTITUDES (U)

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WT-1649

OPERATION HARDTACK—PROJECT 8.3

GROWTH OF FIREBALL RADII AT VERY HIGH ALTITUDES (U)

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ABSTRACT

The purpose was to determine, by photographic means, the modes by which energy is propagated and dissipated from nuclear explosions at very high altitudes. A corollary objective was to document all visible aspects of the detonations for later analysis of any unforeseen phenomena.

The project analyzed films from Shots Yucca, Teak, and Orange. Film records analyzed included 70-mm streak records for very early fireball growth, 35-mm high-speed records for diameter-time relationships up to 2,000 msec, and slow-speed 35- and 70-mm records for late diameter-time data. The films were taken from cameras aboard two RB-36 aircraft.

Shot Yucca had an approximate initial diameter of 40 meters at approximately 0.13 msec and could be measured to a diameter of about 640 meters at 1.5 seconds. Shot Orange had an initial observed diameter of approximately 1.7 km and reached a diameter of 20 km at 30.5 seconds.

Shot Teak was a multiphenomena event. At early times, the configuration of the radiation phase was egg shaped. As time passed, several shocklike phases became discernible. The major vertical and major horizontal measurements of each of these phases were computed.

Because of the uncertainties involved in scaling for high-altitude bursts, no attempt was made to calculate yields.

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FOREWORD

This report presents the final results of one of the projects participating in the military-effect programs of Operation Hardtack. Overall information about this and the other military-effect projects can be obtained from ITR-1660, the "Summary Report of the Commander, Task Unit 3." This technical summary includes: (1) tables listing each detonation with its yield, type, environment, meteorological conditions, etc.; (2) maps showing shot locations; (3) discussions of results by programs; (4) summaries of objectives, procedures, results, etc., for all projects; and (5) a listing of project reports for the military-effect programs.

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Chapter 1

INTRODUCTION

1.1 OBJECTIVES

The purpose was to determine, by photographic means, the modes by which energy is propagated and dissipated from nuclear explosions at very high altitudes. A corollary objective was to document all visible aspects of the detonations for later analysis of any unforeseen phenomena.

1.2 BACKGROUND AND THEORY

High-speed photography of low-altitude detonations, during many operations, has shown that the initial propagation of energy from a nuclear explosion is by [illegible] transport (radiative phase), which is overtaken in a matter of tens of microseconds by hydrodynamic (fireball) transport. Results from Shot 16 during Operation Teapot ([illegible] at 36,600 feet) show that the radiative phase persisted for a considerably longer time than was the case for a similar low-altitude burst (Reference 1). The partition of energy between shock and radiation changes slightly at approximately 24,630 feet; however, a tremendous change was to be expected at extreme altitudes. These phenomena and theoretical considerations are discussed in Reference 2, issued in 1954, prior to Operation Teapot.

The attenuation of radiation of very short wavelength (less than [illegible] angstroms) is complete within a few centimeters at sea level; however, at 250,000 feet these thermal radiations were expected to penetrate several hundred meters. It was postulated that the entire energy release might be radiated without forming any fireball.

Chapter 2

PROCEDURE

2.1 SHOT PARTICIPATION

This project participated in Shots Yucca, Teak, and Orange.

All times given in this section have been corrected for WWVH transit time.

Yucca, a nominal 1.7-kt device, was detonated on 28 April 1958 at local time 1440:00.256 ± 2 msec (Greenwich Mean Time 0240:00.256 ± 2 msec, 28 April 1958). The device was suspended from a balloon at an altitude of 84,683 feet above sea level (ρ_0 = 3.5×10^{-5} gm/cm^3) (Reference 3), and was detonated at a location between Eniwetok and Bikini Atolls in the Eniwetok Proving Ground.

Teak, a nominal 3.8-Mt device, was detonated on 31 July 1958 at local time 2350:05.596 ± 1 msec (GMT 1050:05.598 ± 1 msec, 1 August 1958). The device was carried northwest of the launching pad, to a firing altitude of 250,374 feet ($\rho_0 = 3.4 \times 10^{-8}$ gm/cm^3) (References 3 and 4) by a Redstone missile launched from Johnston Island.

Orange, also a nominal 3.8-Mt device, was detonated in the same manner as Teak, on 11 August 1958 at local time 2330:08.605 ± 1 msec (GMT 1030:08.605 ± 1 msec, 12 August 1958). The burst occurred southwest of the Johnston Island launching pad at an altitude of 141,000 feet ($\rho_0 = 3.2 \times 10^{-6}$ gm/cm^3) (References 3 and 4).

2.2 PHOTOGRAPHIC COVERAGE

Photographic coverage for all events was supplied by cameras mounted in two RB-36 aircraft flying at altitudes of approximately 37,000 feet for Yucca, and 30,500 feet for Teak and Orange. Positioning data for the participating aircraft is given in Table 2.1. Additional cameras were located on the USS Boxer for Yucca and on Johnston Island for Teak and Orange.

The primary high-speed photography was accomplished by means of streak cameras, which utilized 70-mm film to provide a wide field of view. The purpose of this type camera was to produce a film on which was recorded the envelope of the expanding phenomena. To accommodate possible errors in aiming and/or burst position, the cameras were operated without a slit. At a nominal film speed of 20 ft/sec, the cameras, operating with a slit, would be capable of resolving a few microseconds; and without a slit, better than a hundred microseconds. With a 6-inch lens, the spatial resolution is a few meters.

Three streak cameras were used in each aircraft—two mounted to record the vertical growth of the fireball, and one mounted to record its horizontal growth. Because the exposure was relatively unpredictable, the cameras were filtered to respond to different light levels.

One streak camera on the USS Boxer for Yucca and one on Johnston Island for Teak and Orange were equipped with longer lenses so that a record of the envelope of horizontal growth could be obtained in the absence of cloud cover.

Other cameras used included the following: 35-mm Fastax (2,000 frames/sec)—fireball photography; 35-mm Mitchell (24 frames/sec)—fireball photography; 70-mm Hulcher (Edgerton, Germeshausen & Grier modified) cloud ¼ frame/sec)—later stages of cloud formation; 70-mm Maurer (3½ frames/sec)—later stages of cloud formation; and 16-mm gun sight aiming point (64 frames/sec)—distribution of light over the sky (employed ultra-wide-angle lenses) and documentary (both color and black and white).

Timing signals at each station activated the cameras and control equipment. Upon receipt of the time signal, operation of each station was automatic.

2.3 FILM READING AND DATA REDUCTION

The 35-mm films were measured on a Hauser profile-measuring microscope equipped with an Edgerton, Germeshausen & Grier (EG&G) fireball image reading device. The 70-mm streak records on Yucca and Orange were read on a Mann optical comparator, and the Teak streak records were read using a Bausch and Lomb magnifier and a finely scribed 100-micron scale.

The data was processed on the Burroughs E-102 digital computer.

Zero time for the Yucca and Orange streak records was established as the center of the circle that made the best fit to the head of each trace. On Teak, the envelope was less opaque, and streak zero times were measured at the tip of the well-defined inner envelope (Figure 4.25).

Zero times for the 35- and 70-mm framing records were determined by comparison with early diameter measurements taken from the streak records.

Sample camera data and calculation sheets are contained in Appendix A.

2.4 DETERMINATION OF MAGNIFICATION FACTOR

The airborne cameras were mounted perpendicular to the longitudinal axis of the aircraft and elevated to the angles indicated in the photo plan sheets for the various shots (see appendixes).

To determine a magnification factor for relating film dimensions to object size, the distance was calculated along the optical axis of each camera to the point in space where the axis intercepted, at right angles, the plane containing the burst. By measurement on the film of the horizontal and vertical displacements of the image from the center of the frame, the angles between the optical axis of the camera lens and the slant range to burst were obtained. Because the rate of rise of each of the detonations was unknown at the time of analysis and was beyond the scope of the analysis effort, no attempt was made to correct the measurements for viewing geometry. It is hoped that future analysis will yield enough information to enable a correction of diameter values.

The true range ($R_{\phi/a}$) along the optical axis, to be used in determining the magnification factor, was then calculated as follows:

$$R_{\phi/a} = d_1 \cos\alpha \cos\beta + (h_b - h_c)\sin\beta$$

Where: d_1 = horizontal distance—camera to burst

β = camera elevation from horizontal

α = angle between $R_{\phi/a}$ and slant range in horizontal or ground projection

h_b = height of burst

h_c = height of camera

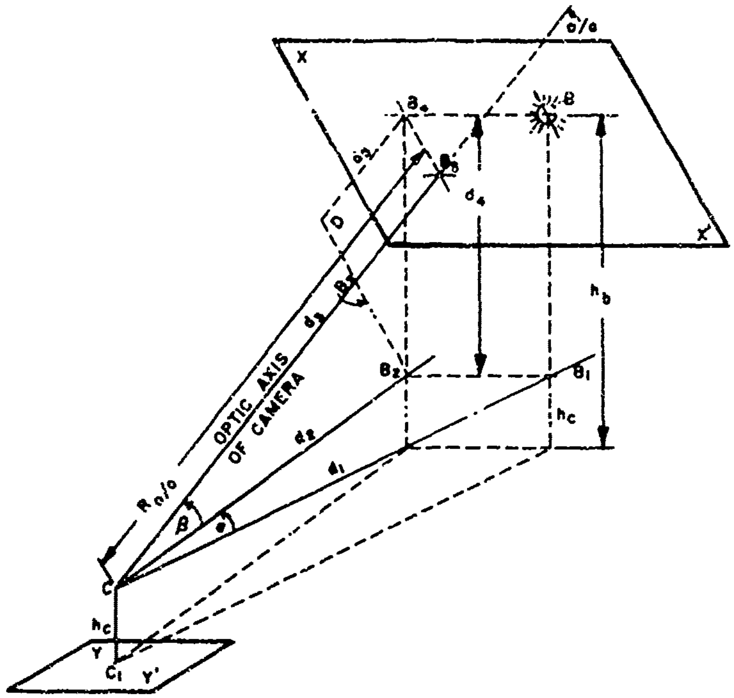
Figure 2.1 is a spatial presentation of the range along the optical axis.

TABLE 2.1 POSITIONING DATA

Location	Coordinates N	Coordinates E	Altitude Z (ft)	Distance, Aircraft to Burst: Horizontal	Distance, Aircraft to Burst: Slant Range
Shot Yucca					
Air zero	4[illegible]1946*	364042*	84,683	—	—
RB-36, 15748 (Station 830.01)	426552*	337621*	36,000	70530	85692
RB-36, 15750 (Station 830.02)	498747*	299340*	37,000	65058	80666
Shot Teak					
Air zero	203144†	194871†	250,3[illegible]	—	—
Launch pad	[illegible]0040†	200580†	~0	—	—
[illegible]er Johnston Island	[illegible]9130†	197855†	~0	—	—
RB-36, 15748 (Station 830.01)	51269†	16432†	[illegible],500	390196	4479[illegible]
RB-36, 15750 (Station 830.02)	[illegible]59†	377278†	30,500	353059	450220
Shot Or[illegible]ge					
Air zero	63198†	196052†	141,009	—	—
Launch pad	200040*	200580†	~0	—	—
Center Johnston Island	199130†	197855†	~0	—	—
RB-36, 15748 (Station 830.01)	461248†	21056†	30,500	434794	446422
RB-36, 15750 (Station 830.02)	461608†	381646†	30,500	439432	453091

* Referenced to Eniwetok coordinate system.

† Referenced to Johnston Island coordinate system.



KEY TO SYMBOLS IN FIGURE:

- B: BURST POINT IN SPACE.
- C: CAMERA LOCATION.
- o/a: OPTICAL AXIS OF CAMERA.
- XX': PLANE THROUGH B PERPENDICULAR TO o/a. THIS IS THE PLANE IN WHICH THE CAMERA SEES THE BURST.
- YY': HORIZONTAL DATUM PLANE.
- C_1: PROJECTION OF C ON YY'.
- CC_1: HEIGHT OF CAMERA = h_c
- B_1: PROJECTION OF B ON HORIZONTAL PLANE THROUGH THE CAMERA.
- $h_b - h_c$: HEIGHT OF BURST MINUS HEIGHT OF CAMERA.
- d_2: PROJECTION OF o/a ON A HORIZONTAL PLANE THROUGH THE CAMERA.
- B_2: PROJECTION OF B_1 ON CB_2.
- B_3: PROJECTION OF B_2 ON o/a.
- B_4: PROJECTION OF B ON VERTICAL PLANE THROUGH o/a
- B_5: PROJECTION OF B ON o/a.
- D: A CONSTRUCTION POINT.
- α: HORIZONTAL OFF-AXIS ANGLE OF THE BURST
- β: THE ANGLE OF ELEVATION OR POSITION ANGLE OF THE o/a.
- h_b: HEIGHT OF BURST.

DERIVATION OF $R_{o/a}$:

ADDITIONAL SYMBOLS:

$R_{o/a}$: RANGE OF BURST ALONG o/a /a

d_1: HORIZONTAL RANGE TO BURST ST

DERIVATION:

$d_2 = d_1 \cos\alpha$

$d_3 = d_2 \cos\beta = d_1 \cos\alpha \cos\beta$

$d_4 = h_b - h_c$

ANGLE $DB_2B_4 = \beta$ BY CONSTRUCTION

$d_5 = d_4 \sin\beta = (h_b - h_c)\sin\beta$

$R_{o/a} = d_3 + d_5$

$= d_1 \cos\alpha \cos\beta + (h_b - h_c)\sin\beta$ sin β

Figure 2.1 Derivation of range along the optical axis ($R_{o/a}$) for off-axis bursts.

Chapter 3

SHOT YUCCA: CAMERA INSTRUMENTATION, ANALYSIS, AND RESULTS

3.1 INSTRUMENTATION AND CAMERA OPERATION

Photographic coverage of fireball growth was provided by cameras mounted in two RB-36 aircraft (Stations 830.01 and 830.02) and by cameras mounted on the USS Boxer (Station 943).

Streak Camera 6 (in aircraft Station 830.01) jammed, but all other airborne cameras obtained records of the detonation. Rain clouds partially obscured the burst from the cameras located on the USS Boxer, and the streak camera at the station jammed; thus, no records suitable for analysis were obtained from Station 943. Analysis for Yucca was accomplished by measurement of records from the airborne camera stations.

The Yucca photo plans and photo loading charts are contained in Appendix B. The aircraft positions and survey data are presented in Figures 3.1 and 3.2.

3.2 RESULTS

The Yucca diameter-time plot is shown in Figure 3.3. Because of apparent differences between the curves of the Yucca streak records, they are plotted separately and labeled with the station number and the density value of the camera filter. Neutral density (ND) filters were used on the streak cameras to attenuate the light. The ND filter is a non-discriminating filter in that it attenuates the light by a fixed percentage over the visible spectrum. ND filters are numbered in accordance with the percentage of light they transmit, e.g., an ND-1 transmits 10 percent of the incident light, while an ND-2 transmits only 1 percent of the incident light. Two facts are readily apparent when these curves are compared: (1) at any comparable time, the diameter values of the records from any one station show a filter dependence, i.e., the greater the filter density, the smaller the diameter; and (2) there is poor agreement among curves plotted from records obtained from cameras equipped with filters of the same density value, e.g., the streak curve from the Station 830.01 camera that used an ND-4 filter is higher at any given time than the curve from the corresponding camera record at Station 830.02.

The difference in image density, attributable to the filtering, is demonstrated when the photographic prints of the three streak records from Station 830.01 are compared (Figures 3.10, 3.11, and 3.12). The camera with the least filtering, ND-3, produced the heaviest image, and the camera with an ND-5 filter produced the faintest image.

The use of filters of different values was necessary because very little information was available on high-altitude detonations, making precalculations of expected light intensity unreliable. The filter values were chosen to provide an exposure variation that would insure adequate coverage over a wide range of light intensity.

To determine the nature of the light distribution across the fireball, microphotometric measurements were made on the streak records (by scanning across each streak, orthogonal to the time axis). Examination of these results showed that the light intensity across

the fireball was nonuniform, rising to a maximum at the fireball center. Figure 3.4 shows a curve of relative light intensity distribution across the face of the fireball. Superimposed on the curve are rectangles representing the filters used and showing the relative range of light intensity encompassed by each. The ND-3 filter passes the widest range of light intensities, while the ND-5 passes the narrowest range. The image width and consequently the calculated diameter is, in this case, dependent upon the intensity range of the filter.

To determine the cause of disagreement among the curves of records made from cameras using similar filters, microphotometric measurements were made on each record at 0.8 msec and at 15 msec. Comparison of microphotometric traces of two records with the same degree of filtering and exposed at the same time showed that the width of the streaks was the same, but the density of the images was markedly different. The trace with the lighter image, when magnified on the optical comparator, was much more difficult to measure because of poor definition at the extremities. In all cases the measurement of the denser image resulted in a higher calculated diameter. The difference in image density is attributed not only to the difficulty in defining the edge of a gradually changing density, but also to variations in the photographic processing. The conditions for processing 70-mm records in the field were such that photosensitometric control was difficult to attain.

An ND-2 filter was used on the Fastax camera mounted in Station 830.02, and the diameter values calculated from measurements of its record are greater at any given time than the values calculated from measurement of the least heavily filtered s . record from either station. This fact supports the observation that the light distribution across the face of the fireball is nonuniform and that the filter density value affects the apparent image size of the streak records.

At approximately 20 msec, an inner core becomes discernible on the film records, and the core grows, assuming the characteristic torus- or doughnut-shaped cloud approximately 4.5 seconds after zero time.

Figures 3.5 through 3.12 show the fireball, the cloud development, and the streak records.

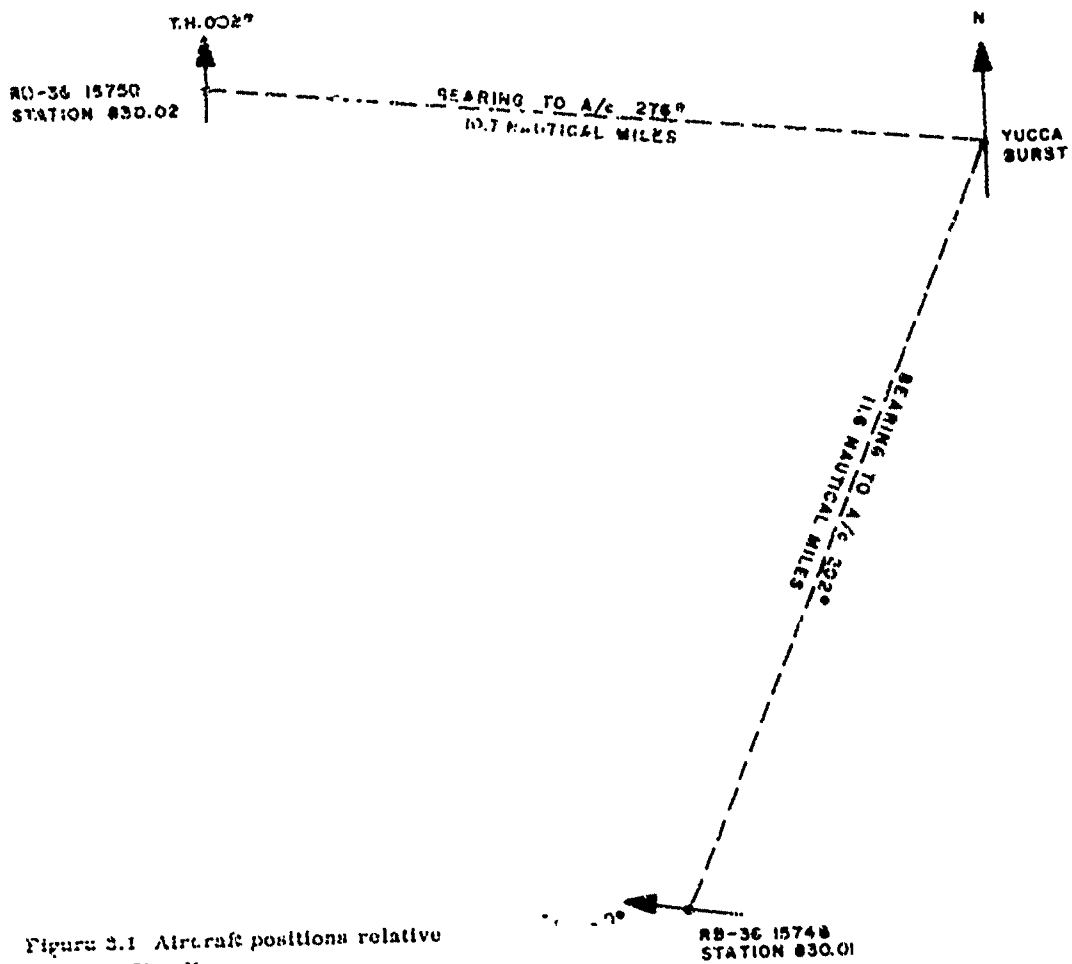


Figure 3.1 Aircraft positions relative to burst, Shot Yucca.

DATE: 5-12-58

SURVEY DATA

GZ STA. Yucca [illegible]

STA.	COORDINATES N	COORDINATES E	COORDINATES Z	FROM Photo Sta. ΔN	FROM Photo Sta. ΔE	FROM Photo Sta. ΔZ	DIST. HOR. FT.	DIST. HOR. M.	TANGENTS ΔE/ΔN	TANGENTS ΔZ/DIST.	ANGLES BRG	ANGLES TILT
G.Z.	491946	364042	035680									
830.4 88-36 [illegible]	[illegible]552	337621	36000	65[illegible]	26421	40680	70530	21498	[illegible]	0.49120	21°00'	34°27'
830.02 88-36 [illegible]	490747	298340	37000	6801	69702	47680	65058	19830	7.57360	0.73280	56°00'	36°14'

ENIWETOK COORDINATE SYSTEM

BEARING ANGLES REPRESENT TRUE AZIMUTH FROM PHOTO STA. TO GROUND ZERO

TILT ANGLES ARE MEASURED [illegible] PHOTO STA. TO SHOT CAB OR AIR ZERO

Figure 3.2 Survey data, Shot Yucca

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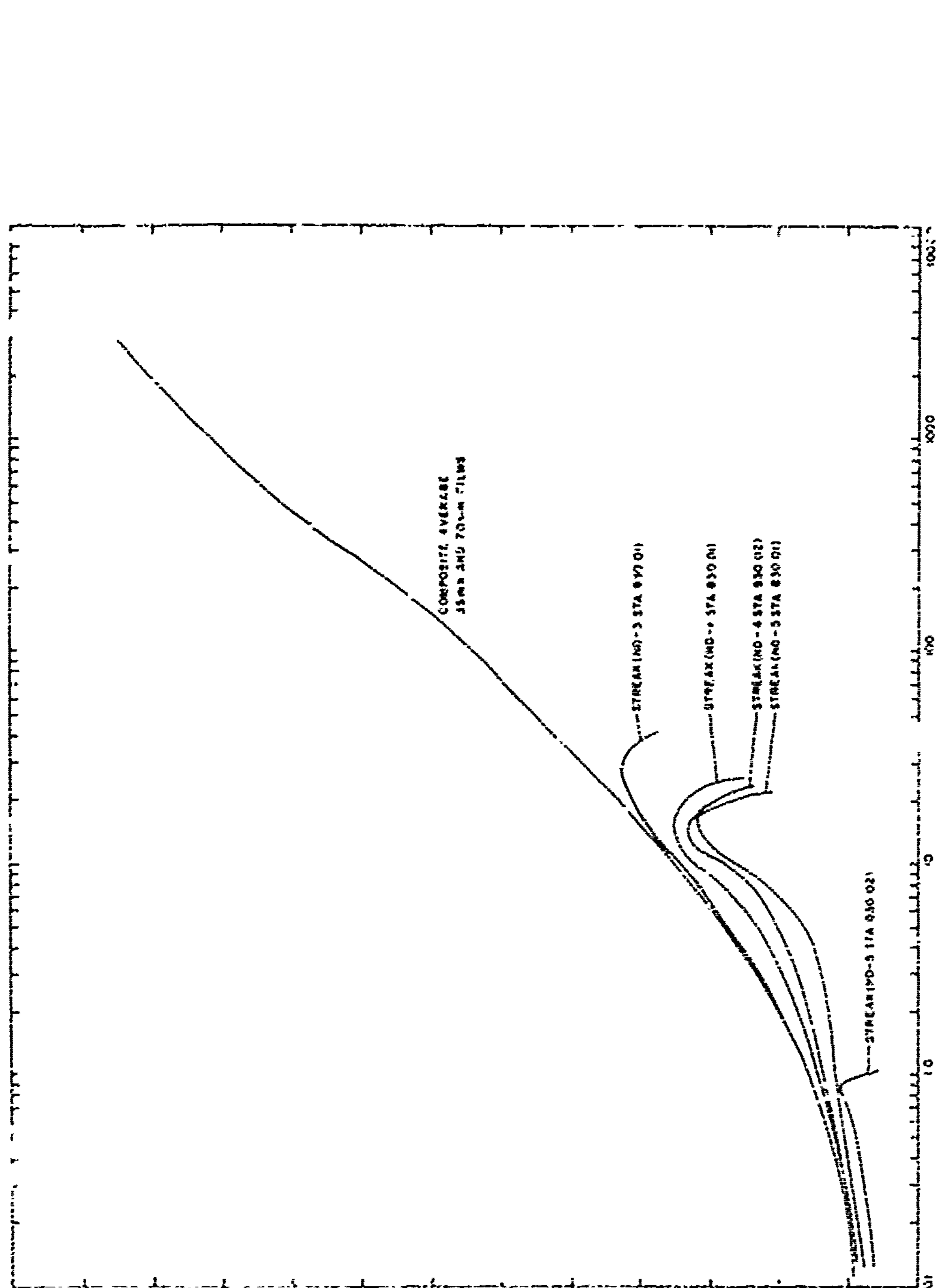


Figure 3.3 Diameter-time plot, Shot Yucca

Figure 3.3 Diameter-time plot, Shot Yucca.

SECRET

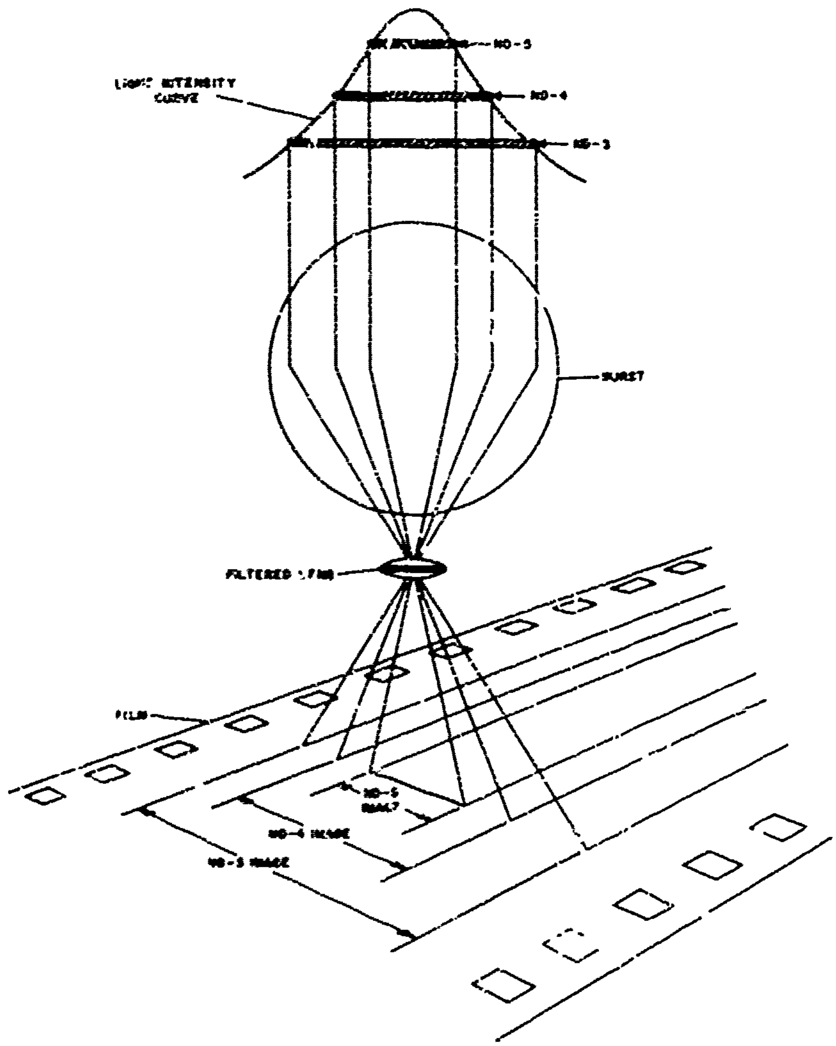


Figure 3.4 Relationship between filter rating and image width of streak records.

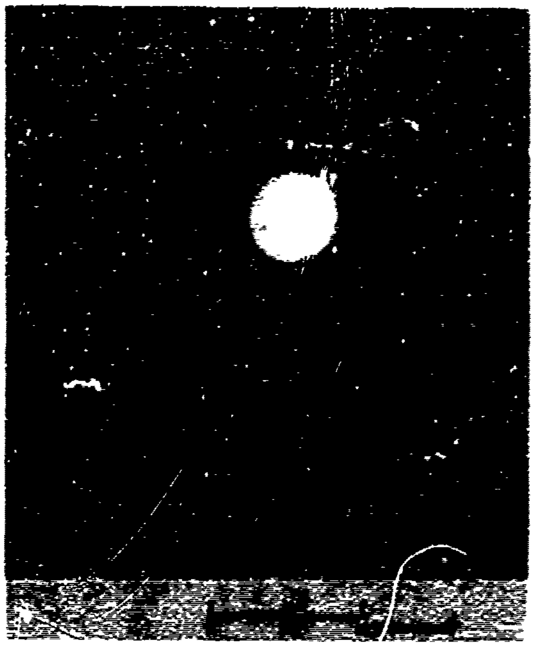


Figure 3.5 Fireball at approximately 0.6 msec, Station 830.02, 35-mm Fastax FF camera, Shot Yucca.

Figure 3.6 Cloud development at approximately 3.0 seconds, Station 830.02, 70-mm Cloud Camera 4, Shot Yucca.

Figure 3.7 Cloud development at approximately 7.5 seconds, Station 830 02, 70-mm Cloud Camera 4, Shot Yucca.

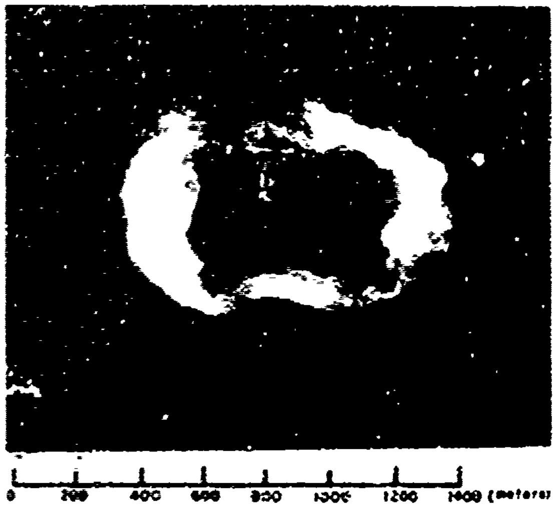


Figure 3.8 Cloud development at approximately 8.5 seconds, Station 830.02, 70-mm Cloud Camera 4, Shot Yucca.

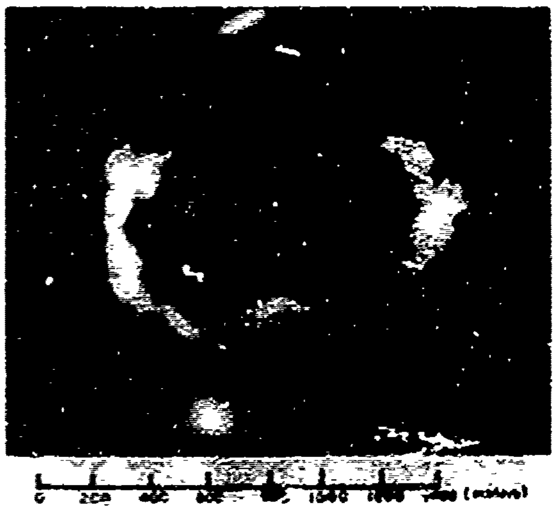


Figure 3.9 Cloud development at approximately 12.5 seconds, Station 830.02, 70-mm Cloud Camera 4, Shot Yucca.

SECRET

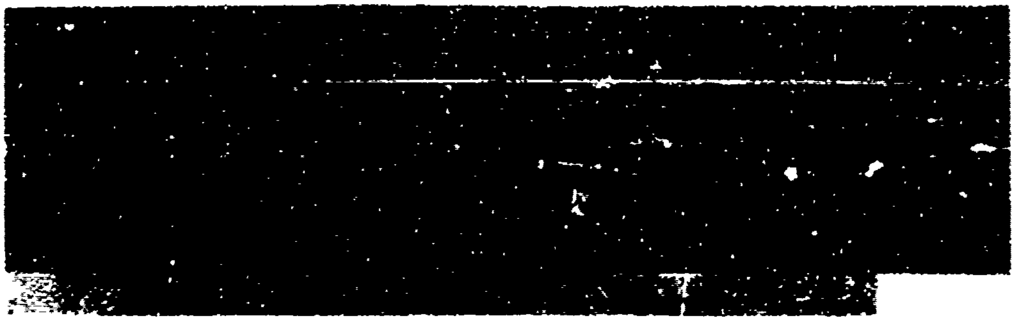


Figure 3.10 Streak record, Camera 3, ND-3 filter (horizontally mounted), Station 830.01, Shot Yucca.

Figure 3.11 Streak record, Camera 2, ND-4 filter (horizontally mounted), Station 830.01, Shot Yucca.

Figure 3.12 Streak record, Camera 1, ND-5 filter (vertically mounted), Station 830.01. Shot Yucca.

Chapter 4

SHOT TEAK: CAMERA INSTRUMENTATION, ANALYSIS, AND RESULTS

4.1 INSTRUMENTATION AND CAMERA OPERATION

Photographic coverage of the Teak detonation was provided by cameras mounted in two RB-36 aircraft (Stations 830.01 and 830.02) and by cameras mounted in a 6 × 6 truck on Johnston Island (Station 831) (Johnston Island coordinate system). The photo plans and photo loading charts are contained in Appendix C. The aircraft positions and survey data are presented in Figures 4.1 and 4.2. All cameras operated normally except the 35-mm Fastax at Station 830.02

The streak camera records from Shot Yucca showed that the ND filter values used on the cameras (ND-5, ND-4, and ND-3) were too high for the light intensity levels of the detonation, consequently, the filter values were reduced (ND-4, ND-3, and ND-1) for the three streak cameras at each station recording the Teak and Orange events. Streak cameras were mounted, as for Yucca, to record both the vertical and horizontal ... spe...

Because the device-carrying missile did not follow the planned course, the detonation ... outside the field of view of all Johnston Island cameras, except ... cameras with very wide fields of view, thus, no data suitable for early-time analysis was obtained from the Johnston Island cameras. Fortuitously, the burst did take place within the fields of view of all of the cameras in both aircraft.

4.2 RESULTS

The phenomena recorded during the Teak shot were much different from those observed on any other detonation. For the purposes of this report, these unique dimensional phenomena have been assigned designators D_0, D_1, D_2, and so forth.

At early times, the fireball was approximately egg-shaped, being symmetrical about the vertical axis and asymmetrical in the vertical direction. At 1 msec, the maximum vertical measurement of the radiative phase D_1 (Figure 4.3) was approximately 17 km, and the maximum horizontal measurement was approximately 13 km. The vertical asymmetry is believed to have been caused by the variation in air density across the fireball. At an altitude of 250,000 feet, the lower air density at the top of the burst provides a longer mean-free path for early radiation, resulting in an egg-shaped configuration. Because of the asymmetry of the fireball, measurements were taken along both the major horizontal and major vertical diameters. The diameter-time plots are shown in Figures 4.3 and 4.4. Linear plots of both horizontal diameter and vertical diameter versus late times are shown in Figures 4.5 and 4.6. As in the case of the Yucca diameter versus time plots, wherever there is important disagreement among streak camera data, the curves have been plotted separately and labeled according to station and filter number.

D_3 is a shocklike phenomenon visible at early times (Figure 4.9). At approximately 900 msec, the light intensity of this phase has fallen off to such a degree that further

measurements on the film record are impossible. The phenomenon designated D_1 appears to be a strong radiation phase brighter than D_0, but much less intense than D_2 (Figure 4.9). D_2 is a high light-intensity phase whose light level drops below the threshold necessary for good film resolution approximately 1 second after zero time.

Another shocklike front moves up the radiative phase of the burst (Figure 4.12). This front was not measured, because there does not appear to be any satisfactory measurement reference point.

The designator D_3 refers to that phase of the detonation that appears in the streak records as a wedge (Figure 4.25) and in the framing camera records as a bright shock (Figure 4.12). The D_3 phase grows rapidly, and approximately 900 msec after zero time, a bright core (D_5) is discernible in the records (Figure 4.12). This core has the apparent elliptical shape that the viewing geometry would be expected to induce on the bomb-debris torus.

About 3 seconds after zero, a shocklike front (D_4) grows from the core (Figure 4.13). This phase can be measured, in the vertical direction only, to approximately 8 seconds, after which time the light intensity drops sufficiently to preclude further measurement.

The linear plot of horizontal diameter versus late time (Figure 4.5) shows an apparent disagreement between D_5 values from Mitchell (35-mm) and Maurer (70-mm) films. The differences are probably due to the degree of personal judgment required in reading the larger and less well-defined images of the 70-mm Maurer records.

Approximately 7 seconds after zero, a luminescent phenomena rises from the bottom of the radiation envelope (Figures 4.15 and 4.16).

A strong aurora first becomes apparent in the photographs approximately 50 m[illegible] after zero (Figure 4.16).

[illegible]graphic prints showing phenomena growth are shown in Figures 4.7 through 4.22. Several prints (Figures 4.7 and 4.9) show bright spots below the burst; these are internal camera reflections and are not functions of the burst.

Streak records are shown in Figures 4.23 through 4.26. Density variations across the streak image are apparent on some prints (Figures 4.25 and 4.26). These variations are attributed to the photographic processing techniques employed. Because of inadequate field facilities, processing under strict photo sensitometric control was not possible.

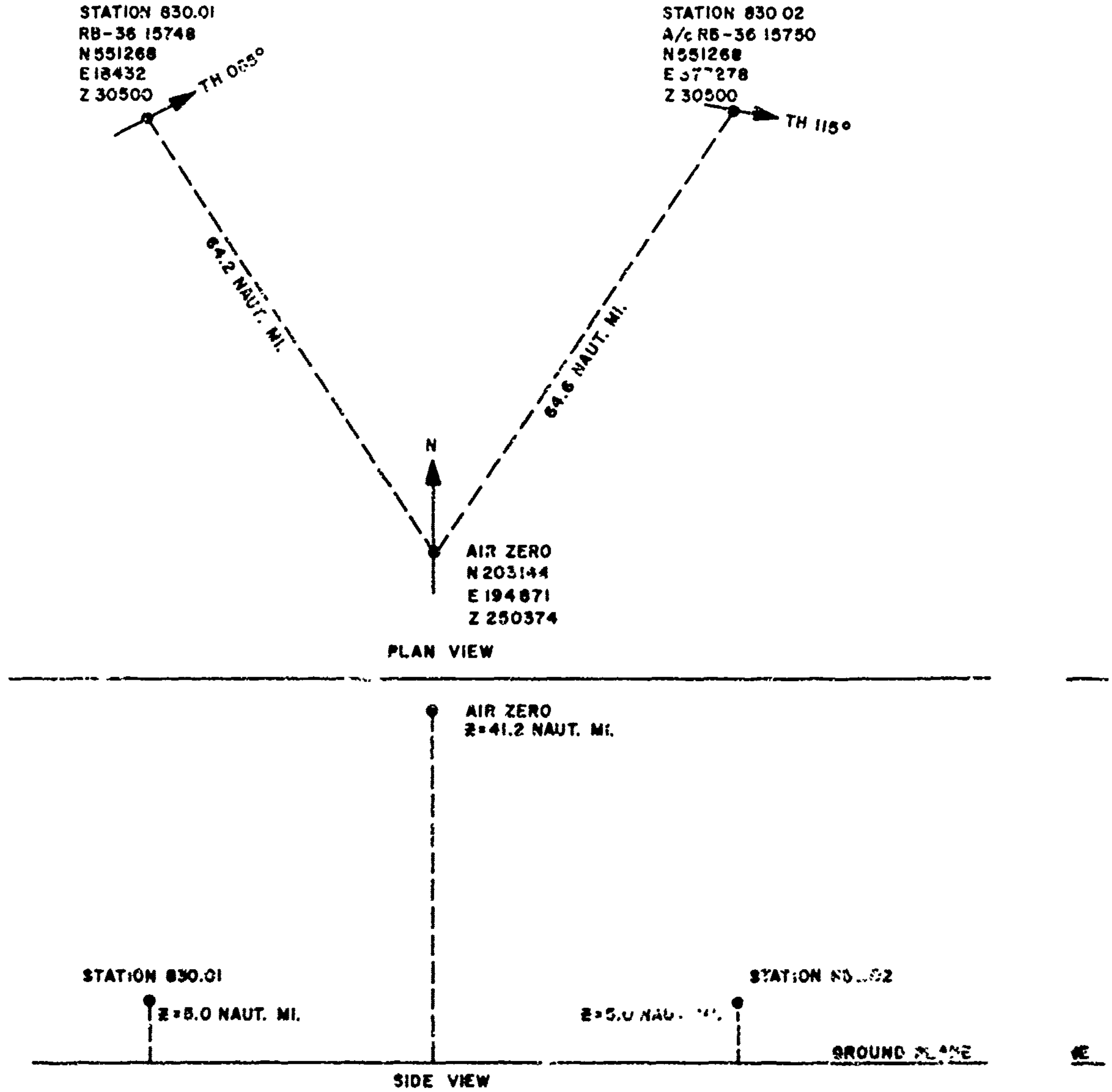


Figure 4.. Aircraft positions relative to burst, Shot Teak.

TEAK

DATE 12/11/58 **SURVFY DATA** GZ STA. HIGH ALTITUDE

STA.	COORDINATES			FROM Photo Sta.			DIST. HOR.		TANGENTS		ANGLES	
	N	E	Z	ΔN	ΔE	ΔZ	FT.	M.	ΔE/ΔN	ΔZ/DIST.	BRG	TILT
GZ	203144	194871	250374									
830.01 28-30 [illegible]	551268	18432	30500	$\bar{3}48124$	176439	219874	390196	118933	$\bar{0}.506828$	0.563496	153°7'26"	29°24'4"
830.02 28-26 [illegible]	551260	377278	30500	$\bar{3}48124$	$\bar{1}82407$	219879	393059	119806	0.523911	0.555392	207°39'[illegible]	29°13'20"
831 [illegible]	200450	200520	~8	2694	$\bar{5}659$	250366	6267	1910	2.100:44	33 9498	295°27'25"	88°34'

JOHNSTON ISLAND COORDINATE SYSTEM

BEARING ANGLES REPRESENT TRUE AZIMUTH FROM PHOTO STA TO GROUND ZERO

TILT ANGLES ARE MEASURED FROM THE PHOTO STA. TO SHOT GAB OR AIR ZERO.

Figure 4.2 Survey data, Shot Teak.

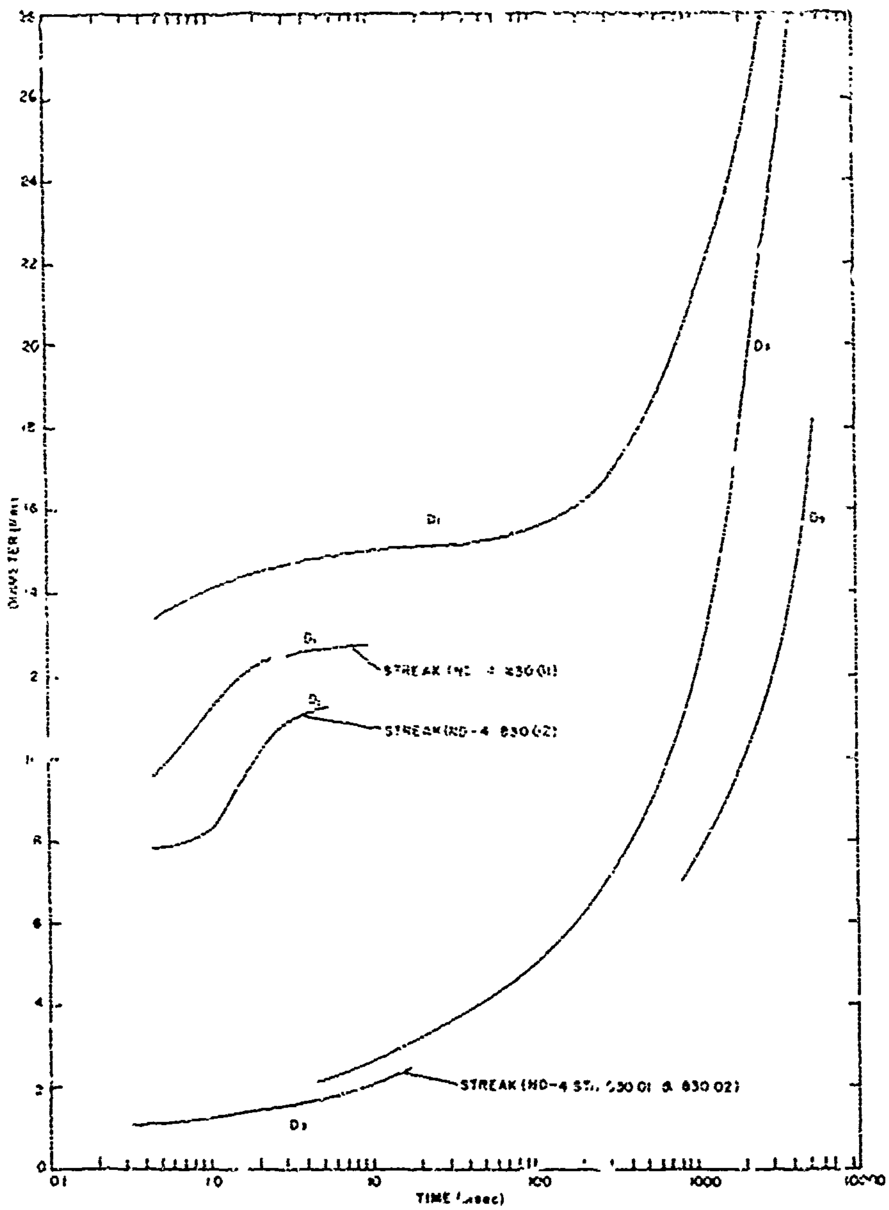


Figure 4.3 Horizontal diameter-time plot, Shot Teak.

SECRET

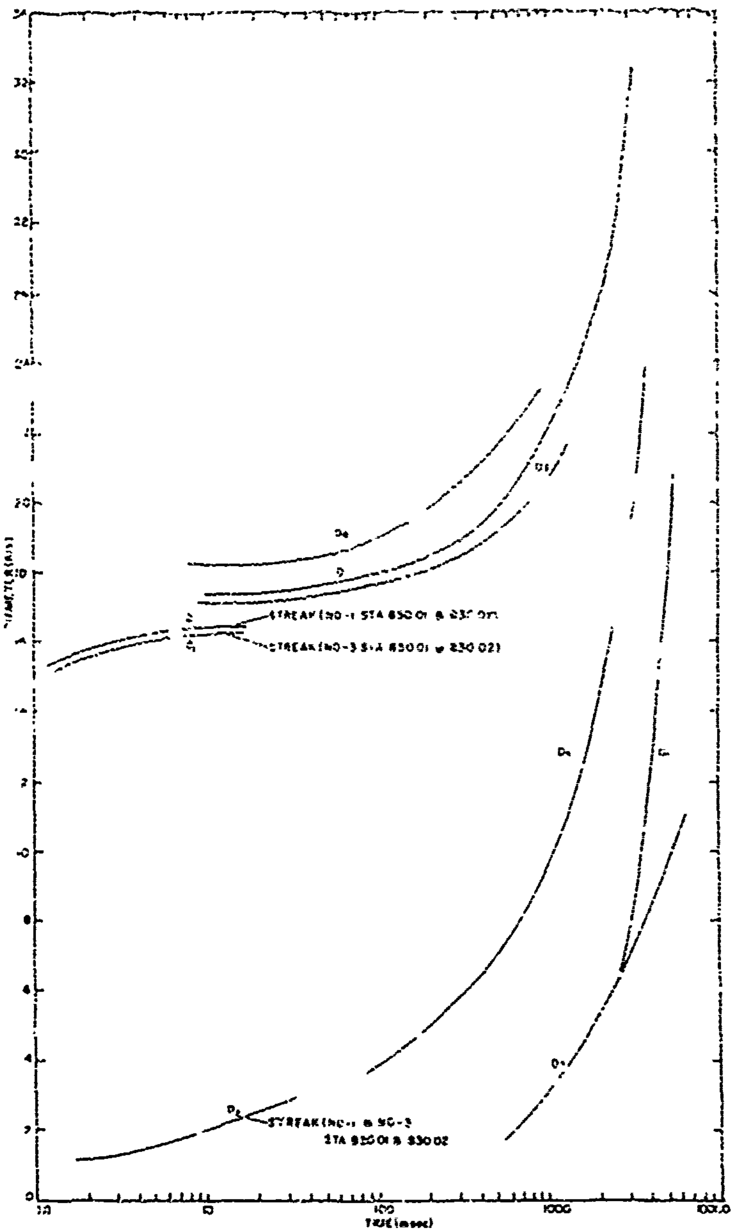


Figure 4.4 Vertical diameter-time plot, Shot Teak.

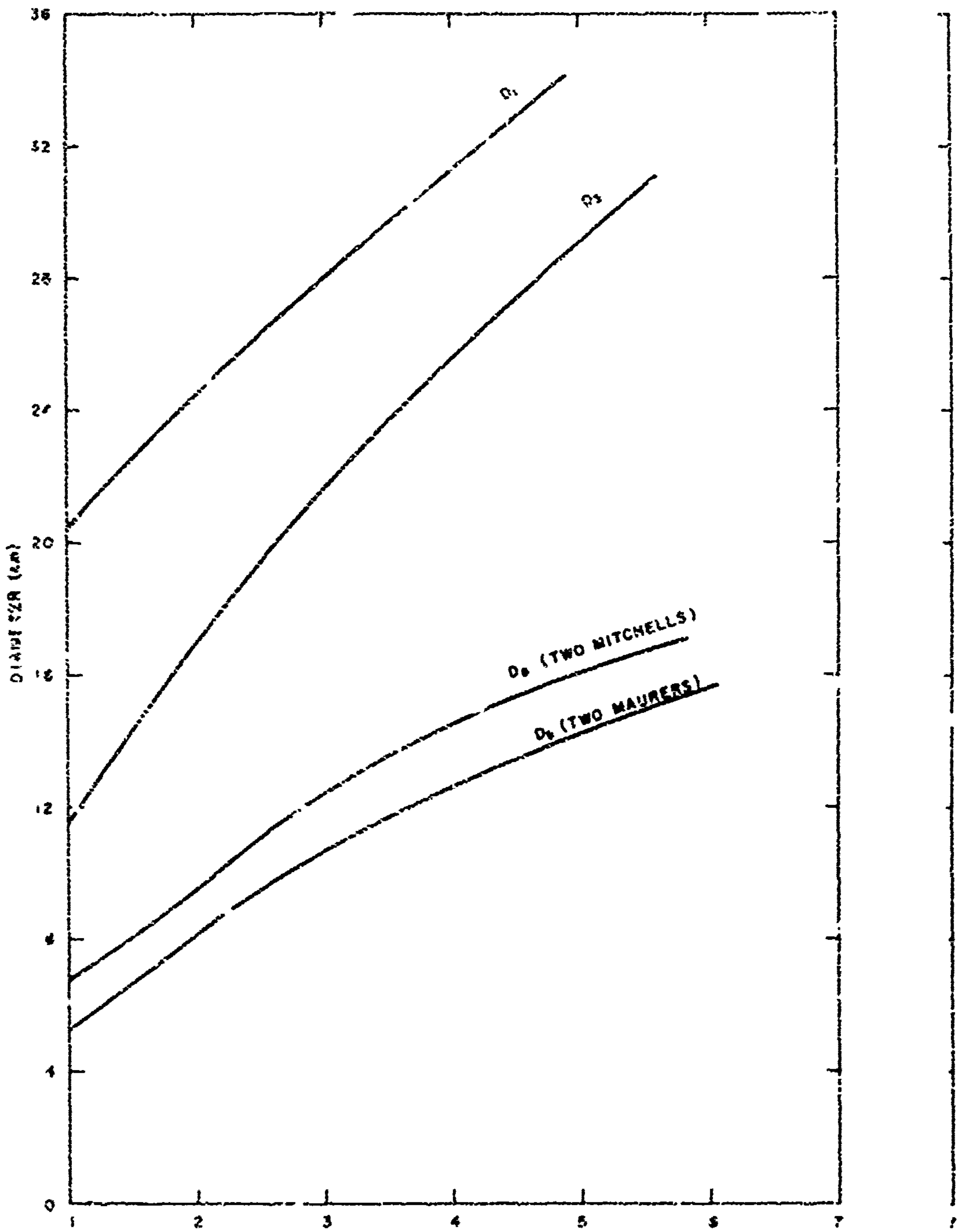


Figure 4.5 Horizontal diameter versus late time, Shot Teak.

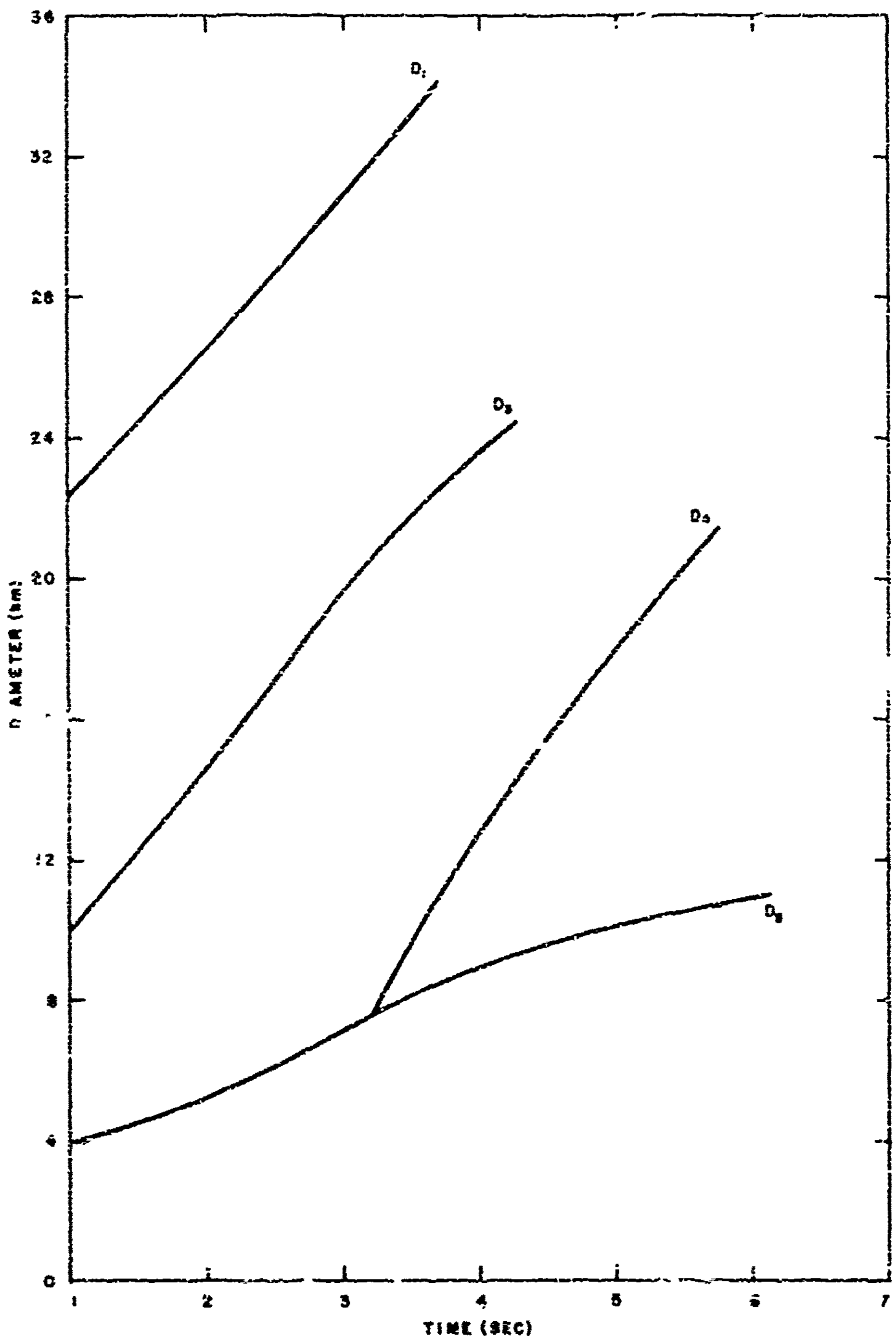


Figure 4.6 Vertical diameter versus late time, Shot Teak.

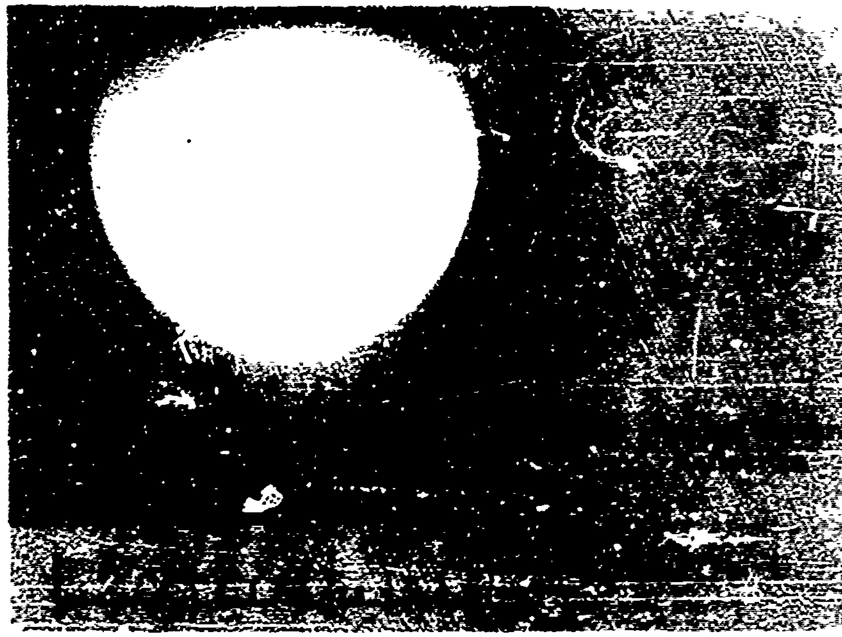


Figure 4.7 Fireball at 0.68 msec, Station 830.01, 35-mm Fastax FF-1 camera, Shot Teak.

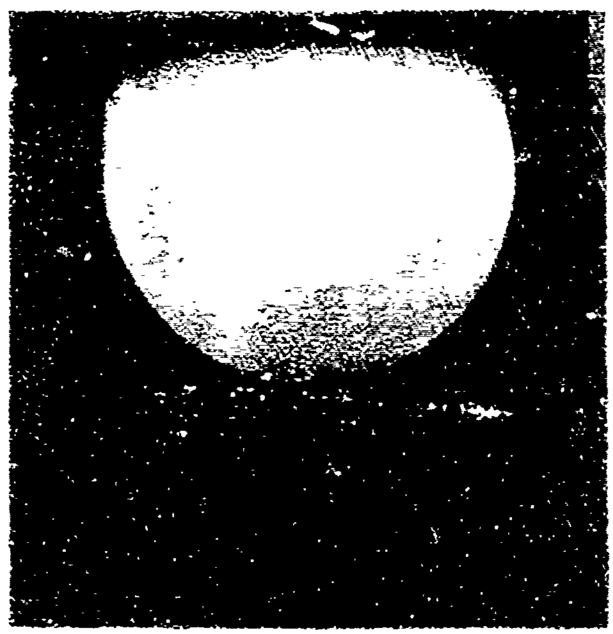


Figure 4.8 Fireball at 9.96 msec, Station 830.01, 35-mm Fastax FF-1 camera, Shot Teak.

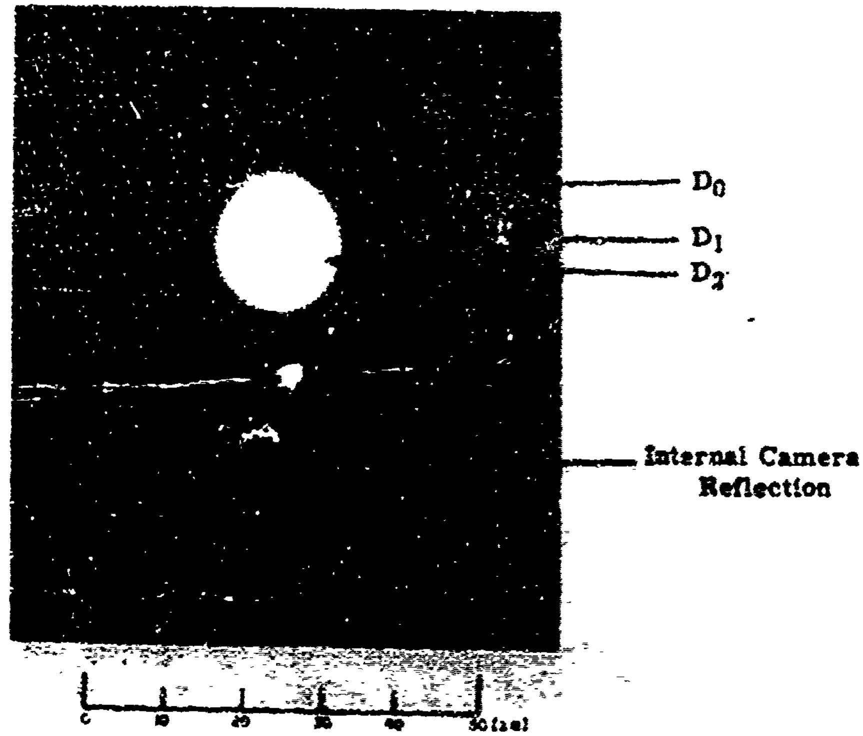


Figure 4.9 Fireball at 50 msec, Station 830.01, 70-mm Maurer M-4 camera, Shot Teak.

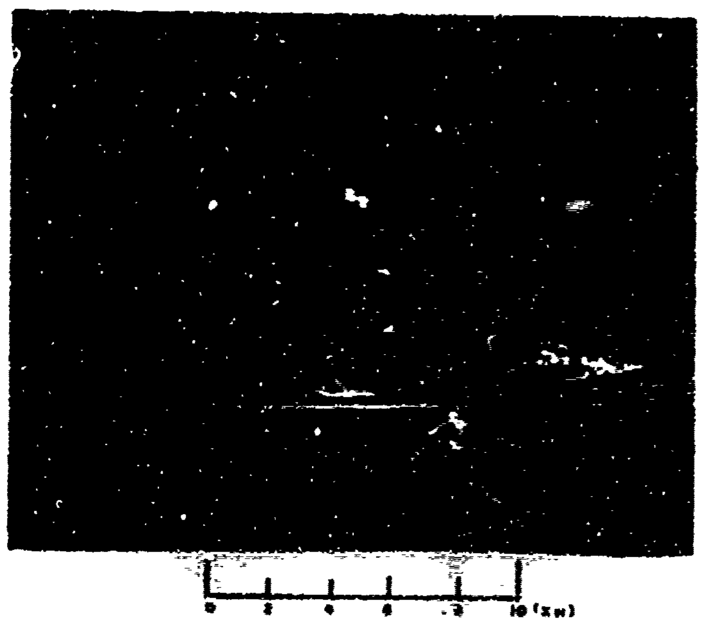


Figure 4.10 Fireball at 281 msec, Station 830.01, 35-mm Fastax camera, Shot Teak.

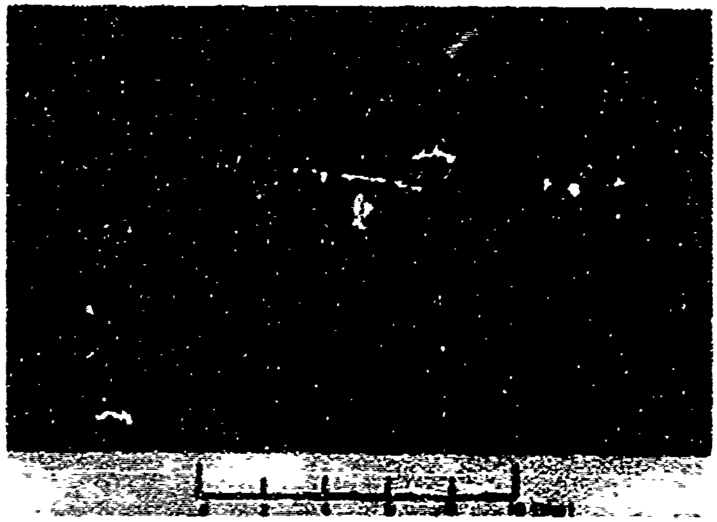


Figure 4.11 Fireball at 547 msec, Station 830.01, 35-mm FX camera, Shot Teak.

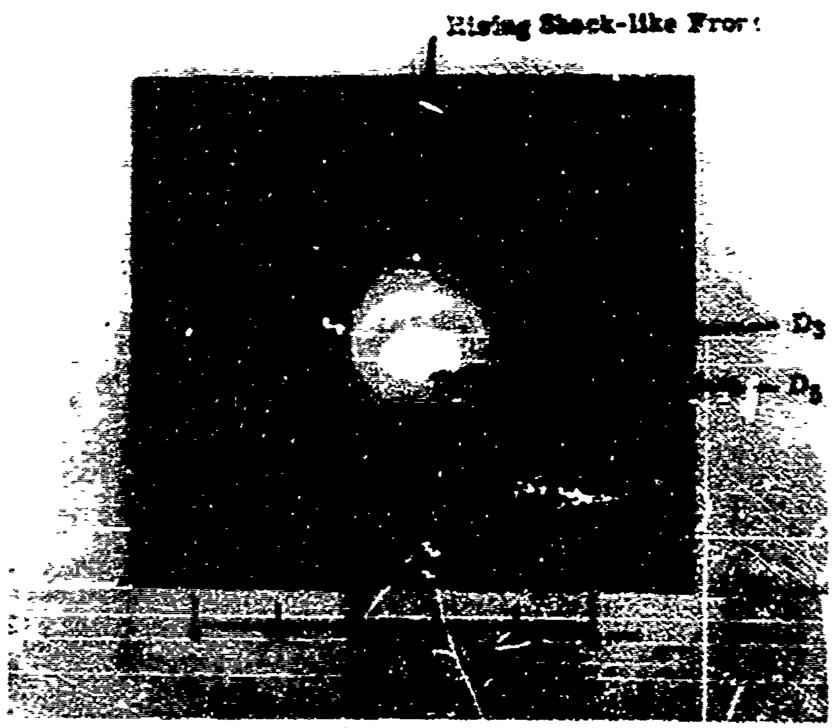


Figure 4.12 Fireball at 2.45 seconds, Station 830.01, 70-mm Maurer M-4 camera, Shot Teak.

Figure 4.13 Fireball at 3.95 seconds, Station 830 01, 70-mm Maurer M-4 camera. Shot Teak.

Figure 4.14 Fireball at 5.15 seconds, Station 830.01, 70-mm Maurer M-4 camera, Shot Teak.

Figure 4.15 Fireball at 7.55 seconds, Station 530.01, 70-mm Maurer M-4 camera, Shot Teak.

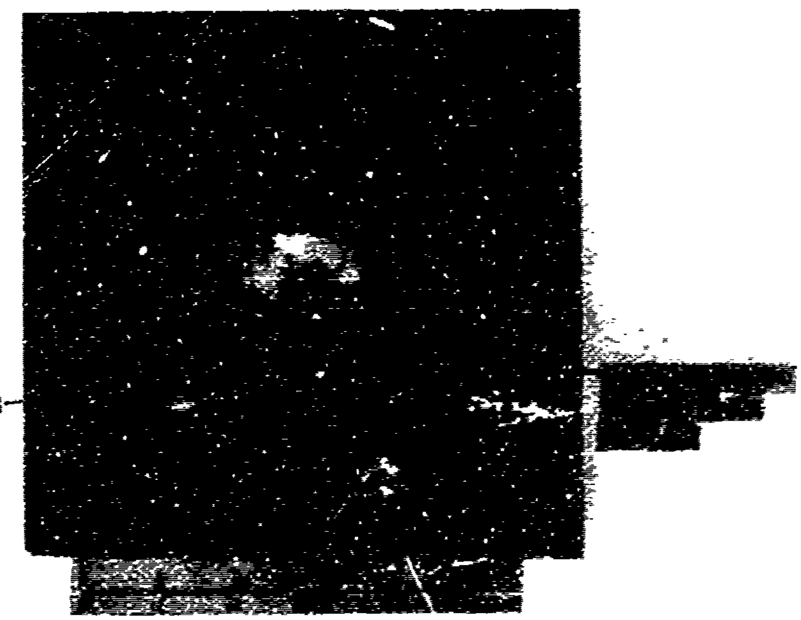


Figure 4.16 Fireball at 10.85 seconds, Station 830.01, 70-mm Maurer M-4 camera, Shot Teak.

Figure 4.17 Fireball at 19.85 seconds, Station 830.01, 70-mm Maurer M-4 camera, Shot Teak.

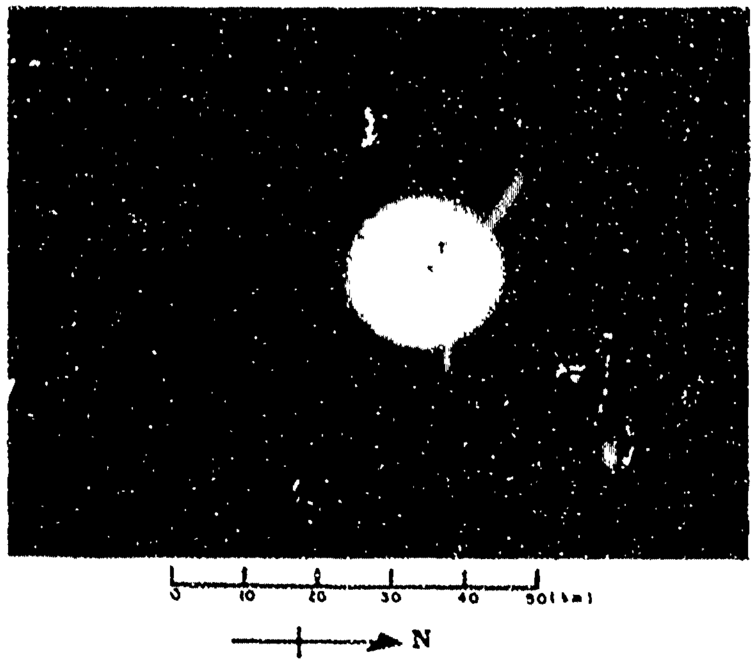


Figure 4.18 Fireball at approximately 3 seconds, Station 831, 70-mm Hulcher H-16 camera, Shot Teak.

Figure 4.19 Fireball at approximately 4 seconds, Station 831, 70-mm Hulcher H-10 camera, Shot Teak

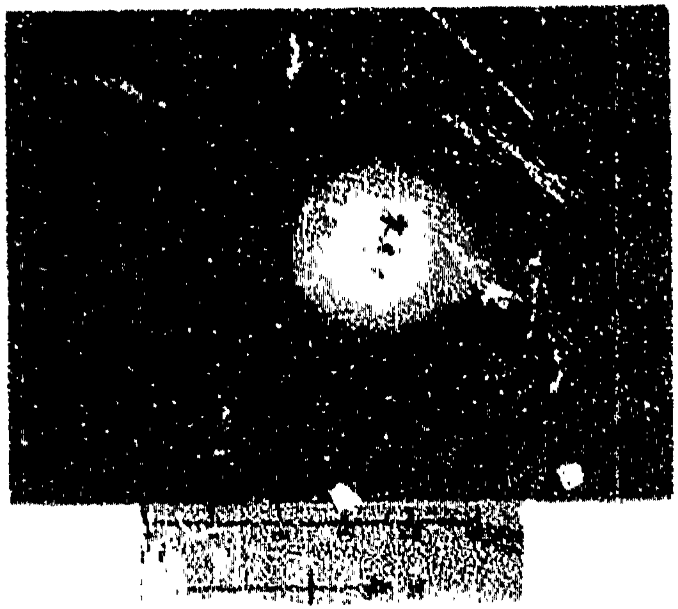


Figure 4.20 Fireball at approximately 5 seconds, Station 831, 70-mm Hulcher H-10 camera, Shot Teak

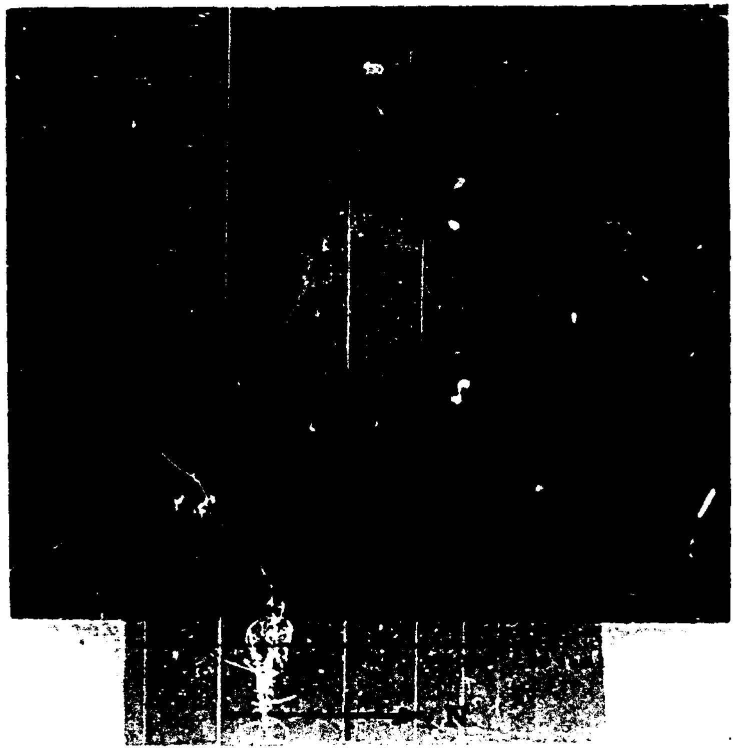


Figure 4.21 Fireball at approximately 6 seconds, Station 831, 70-mm Hulcher H-10 camera, Shot Teak.

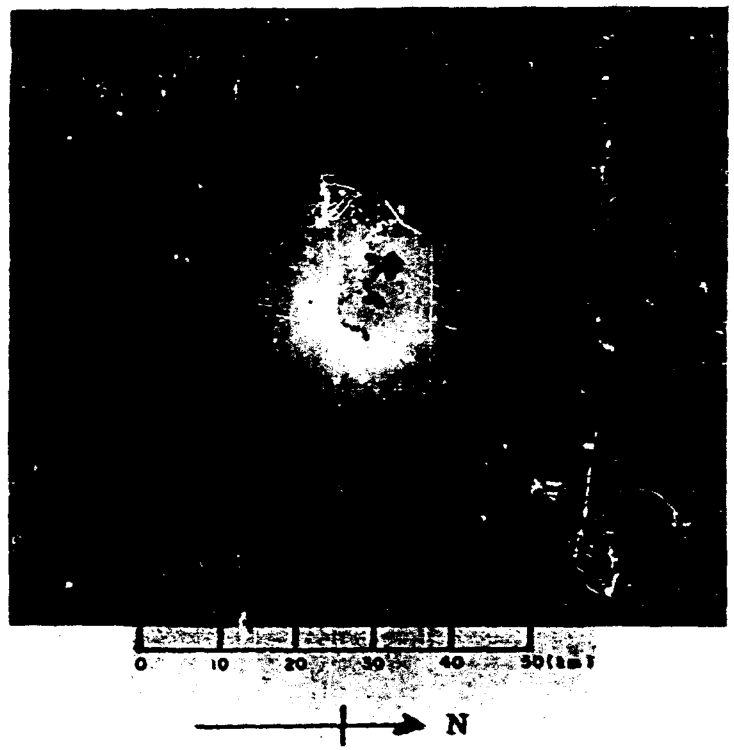


Figure 4.22 Fireball at approximately 7 seconds, Station 831, 70-mm Hulcher H-10 camera, Shot Teak.

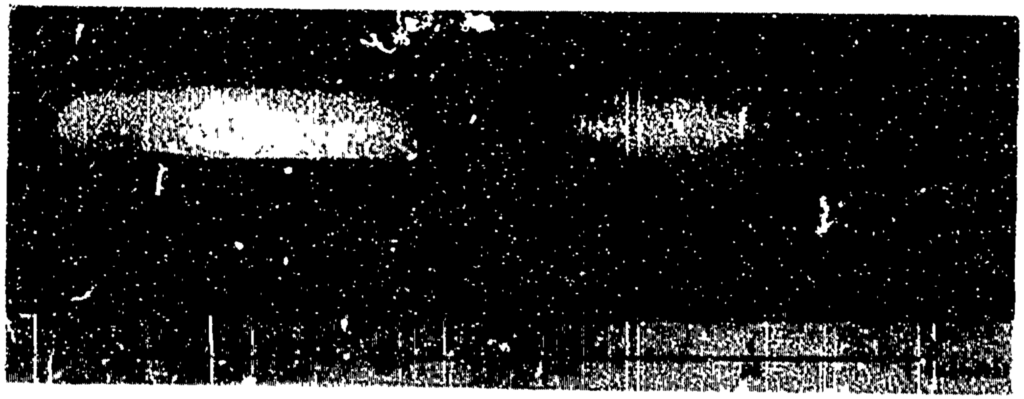


Figure 4.23 Streak record, 70-mm Streak-STR-6 (filter ND-1), Station 830.02 (horizontally mounted), Shot Teak.

Figure 4.24 Streak record, 70-mm Streak-STR-4 (filter ND-4), Station 830.02 (vertically mounted), Shot Teak.

Figure 4.24 Streak record, 70-mm Streak-STR-4 (filter ND-4), Station 830.02 (vertically mounted), Shot Teak.

Figure 4.25 Streak Record, 70-mm Streak-STR-5 (filter ND-3), Station 830.02 (horizontally mounted), Shot Teak.

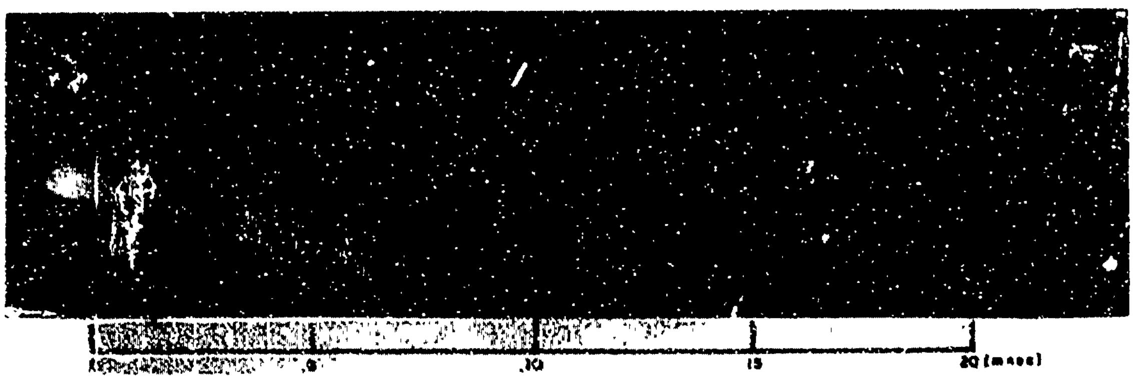


Figure 4.26 Streak record, [illegible] Streak-STR-2 (filter ND-3), Station 830.01 (horizontally moun[illegible], Shot Teak.

Chapter 5

SHOT ORANGE: CAMERA INSTRUMENTATION, ANALYSIS, AND RESULTS

5.1 INSTRUMENTATION AND CAMERA OPERATION

The camera stations for Orange were the same as for Teak. All cameras functioned properly, but cloud cover prevented the cameras at Johnston Island from obtaining usable records, thus, analysis of the Orange fireball growth was restricted to the records from the aircraft stations. The aircraft positions and survey data are presented in Figures 5.1 and 5.2. The photo plans and photo loading charts are contained in Appendix D

5.2 RESULTS

The diameter versus time plot for Orange is presented in Figure 5.3. Where disagreement in streak record curves is significant, each curve is plotted separately and labeled with station number and filter rating. Microphotometric measurements of [illegible] pe made on the Yucca streak records show that the disagreement among records is [illegible] ributable to the filters employed and the method of photographic processing used. Agr[illegible]ent among [illegible] cords from cameras using filters of the same value was much better than in the case of Yucca, probably because of the higher light-intensity levels of the Orange detonation, [illegible] because the filters used on the Orange cameras were of lower density values than those chosen for Yucca. Enough light passed the filters [illegible] present an image that was easily measured despite image density differences introduced by field-processing techniques used on the streak records.

The Orange fireball exhibits vertical asymmetries at early times similar to those noticed on the Teak records (Figure 5.6). but by 250 msec the configuration of the fireball image is essentially circular. At the lower altitude of the Orange detonation, the differential in air density between the top and bottom of the fireball is much less than that [illegible] Shot Teak, so the asymmetry is not as pronounced or as persistent as was noted during Teak.

The emulsion of each of the first three frames of the 24 frames/sec Mitchell camera records was burned, and the fourth frame had a solarized image, giving an indication of the high intensity level of the early light from the detonation. Diameters calculated from measurements of these frames were in poor agreement with diameters from other films at comparable times. The diameters calculated from subsequent frames were in good agreement, thus, the measurements from the first four frames of each Mitchell record were not considered representative of the Orange diameter-time growth and were excluded from the plot.

At approximately 20 msec, a core is discernible on the 35-mm Fastax record This core assumes a circular shape (Figure 5.7) and rises to the top of the fireball, where it appears to rise out of the top of the fireball envelope (Figure 5.16). A large luminescent halo effect starting at the bottom of the envelope (Figures 5.7 through 5.12) appears

around the core at approximately 286 msec. As the core rises, the halo diameter appears to to diminish until it converges into the core. At very late times, the bottom of the envelope seems to rise, creating a vortexlike appearance (Figure 5.16).

At late times, an aurora, less pronounced than that associated with Shot Teak, is discernible on 70-mm Orange records.

The spot which appears on the face of the Orange envelope (Figures 5.10 through 5.12) is discernible in photographs taken from both airborne stations and has the proper northerly orientation to indicate a possible association with the vehicle launched at Johnston Island.

Inspection of the aircraft records of the Orange debris torus shows it to be nearly circular over the first few seconds.

If the toroid were assumed to be circular in a plane parallel to the surface of the earth, as the Teak toroid was, the Orange toroid should be more nearly elliptical than Teak's appeared in the aircraft records, because the elevation angle of Orange above the horizontal is half that of Teak. This is not the case; in fact, the opposite is true. (Compare Figures 4.10, 4.11, and 4.12 with Figures 5.7, 5.8, 5.9, 5.12, and 5.13). This would lead to the assumption that the Orange torus is circular in a plane that is close to being perpendicular to the surface of the earth.

Two explanations of this paradoxical observation are offered. (1) The orientation of the early torus might be a function of the axis of the missile at detonation time, although this is considered highly improbable. Presumably, the Teak missile was still climbing at detonation; whereas the Orange missile, whose track was some 20 nautical miles [illegible] and 20 nautical miles up from its launch point, might have detonated at apogee. I[illegible] this difference in positions, it might be inferred that the early torus was propaga[illegible] in a [illegible]ogonal to the track axis. (2) The mechanisms that effect the rising vort[illegible]ng action common to all bomb debris could have influenced the Teak debris at much earlier times th[illegible] it influenced the Orange debris. This inference does not, however, explain the [illegible] hole in the Early Orange debris.

A third possibility, a discussion of which is beyond the scope of this report, is the interaction between the fireball plasma and the earth's magnetic field.

Photographic records obtained during the Orange detonation are presented in Figures 5.4 through 5.20.

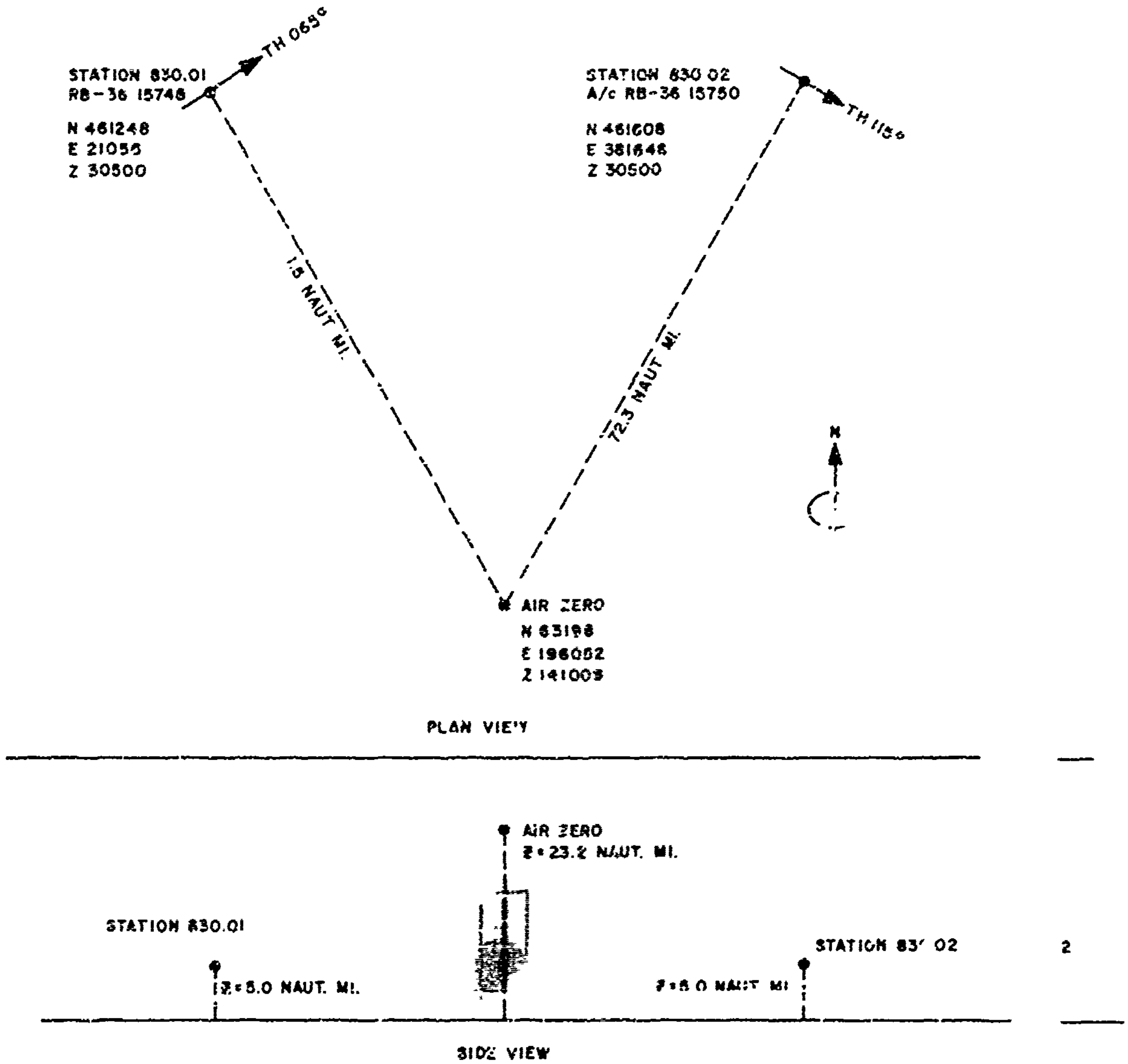


Figure 5.1 Aircraft positions relative to burst, Shot Orange.

DATE 12/11/58 **SURVEY DATA** GZ STA. HIGH ALTITUDE

ORANGE

STA.	COORDINATES			FROM Photo Sta.			DIST. HOR.		TANGENTS		ANGLES	
	N	E	Z	ΔN	ΔE	ΔZ	FT.	M.	ΔE/ΔN	ΔZ/DIST.	BRG	TILT
GZ	63198	196052	141004									
830.01	761248	21056	30500	-398050	174996	110509	434344	132521	0.439633	0.254104	135°16'5"	14°15'38"
830.02	461608	381646	30500	-398410	-185544	110509	439432	133941	0.465837	0.251481	204°58'	14°6'58"
831	200450	200530	-8	-137252	-4478	141000	137324	41857	0.032626	1.026775	187°52'5"	45°45'24"

JOHNSTON ISLAND COORDINATE SYSTEM

BEARING ANGLES REPRESENT TRUE AZIMUTH FROM PHOTO STA. TO GROUND ZERO.

TILT ANGLES ARE MEASURED FROM THE PHOTO STA. TO SHOT CAB OR AIR ZERO.

Figure 5.2 Survey data, Shot Orange.

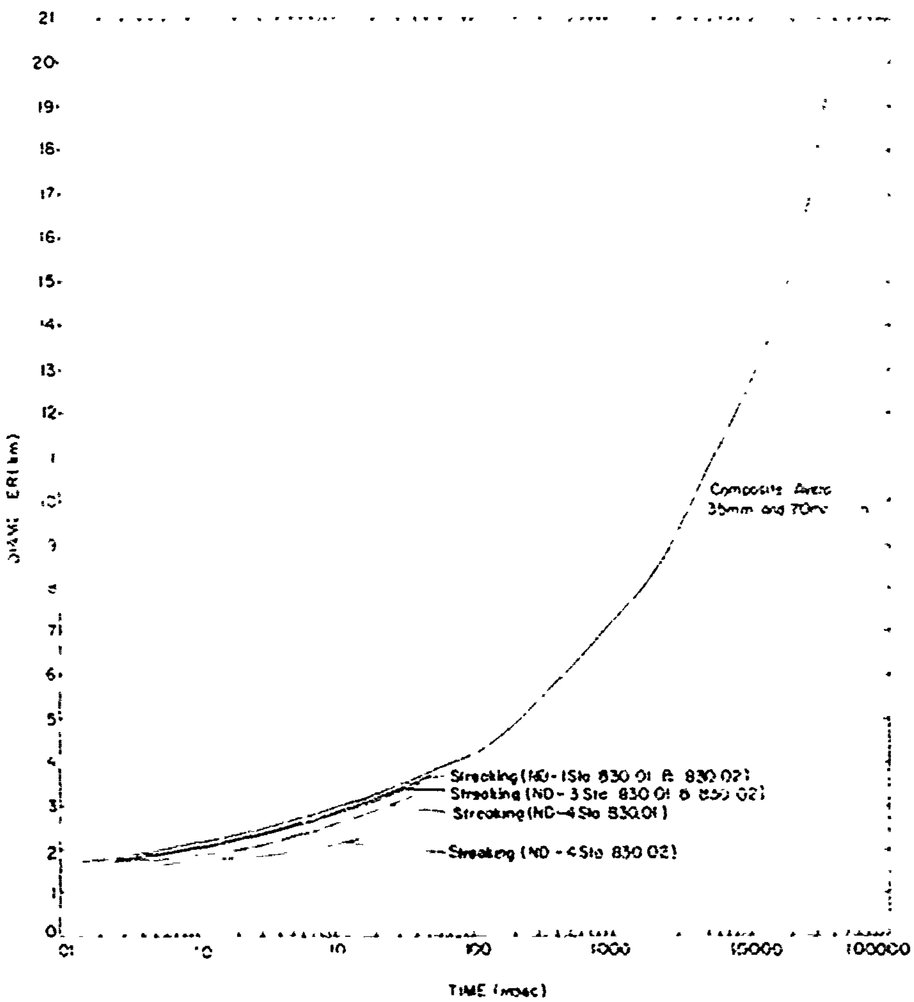


Figure 5.3 Diameter-time plot, Shot Orange.

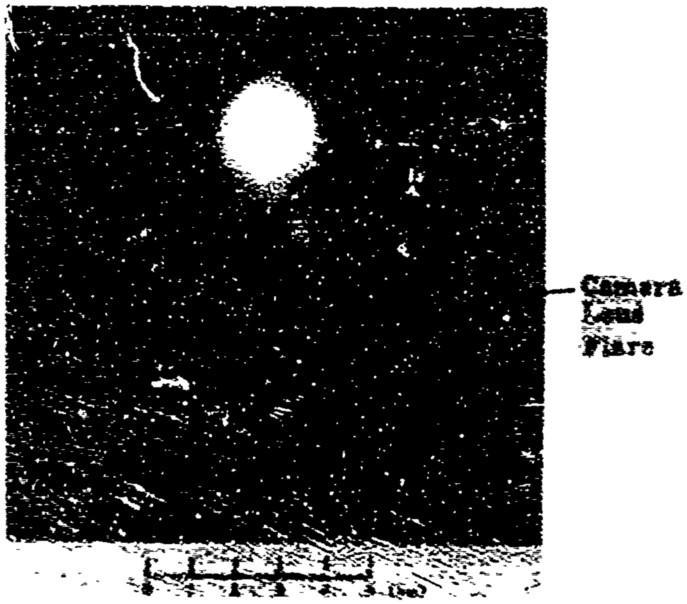


Figure 5.4 Fireball at 0.58 msec, Station 830.01, 35-mm Fastax FF-1 camera, Shot Orange.

Figure 5.5 Fireball at 9.68 msec, Station 830.01, 35-mm Fastax FF-1 camera, Shot Orange.

Figure 5.6 Fireball at 52 msec, Station 830.01, 35-mm Fastax FF-1 camera, Shot Orange.

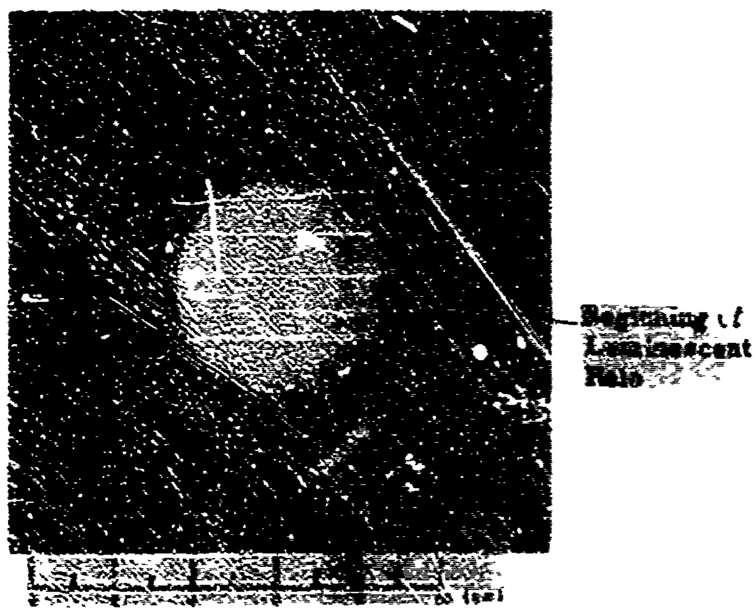


Figure 5.7 Fireball at 286 msec, Station 830.02, 35-mm Fastax FF-2 camera, Shot Orange.

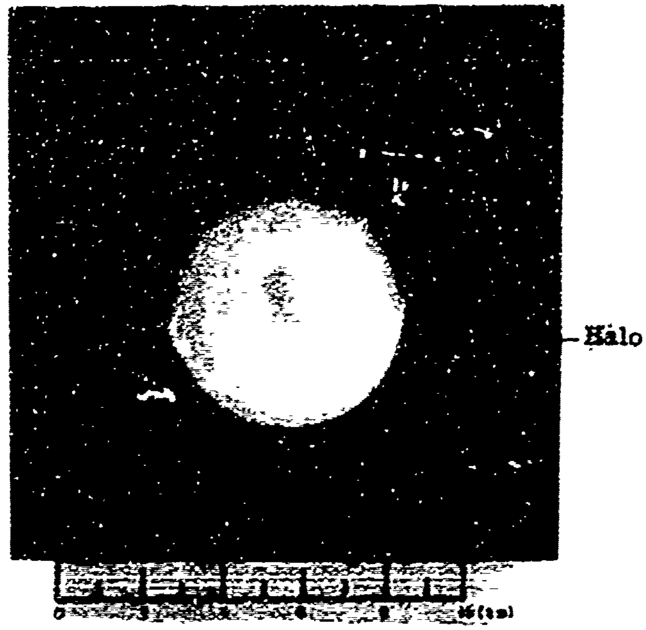


Figure 5.8 Fireball at 430 msec, Station 830.02, 35-mm Fastax FF-2 camera, Shot Orange.

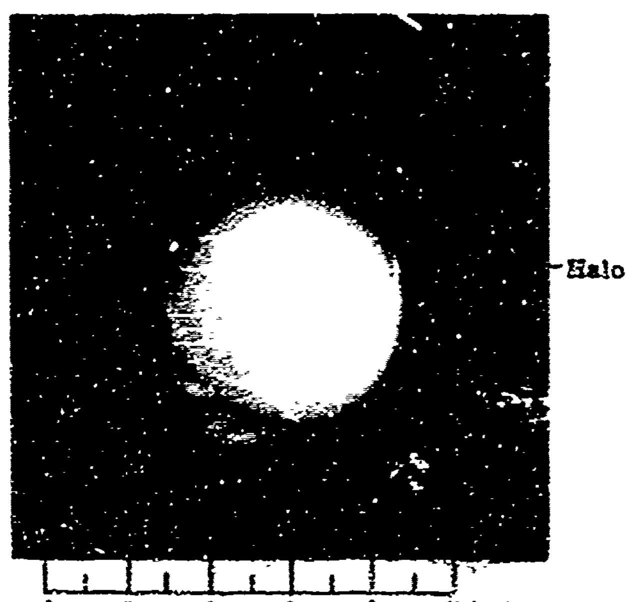


Figure 5.9 Fireball at 596 msec, Station 830.02, 35-mm Fastax FF-2 camera, Shot Orange

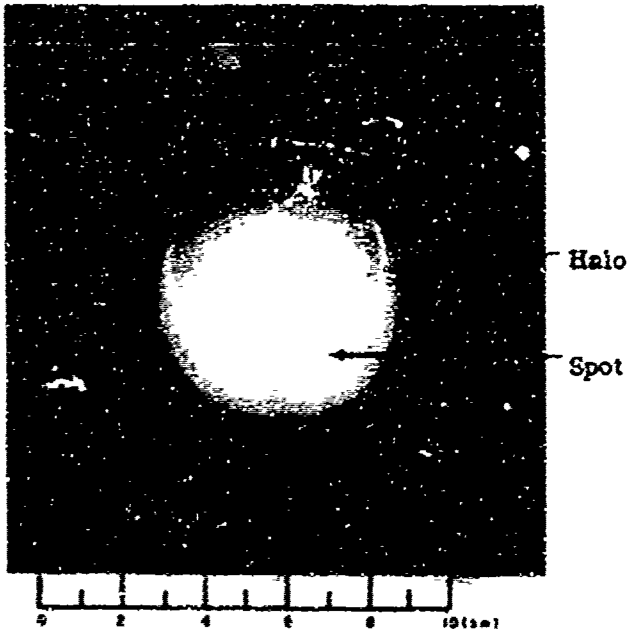


Figure 5.10 Fireball at 803 mse.. Station 830.02, 35-mm F. FF-2 camera, Shot Orange. (Note circular torus.)

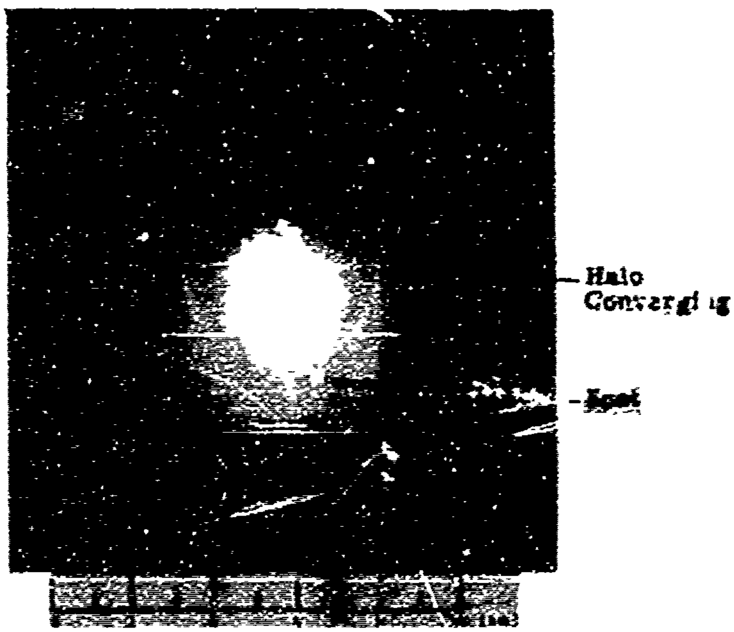


Figure 5.11 Fireball at 969 msec, Station 830.02, 35-mm Fastax FF-2 camera, Shot Orange. (Note circular torus.)

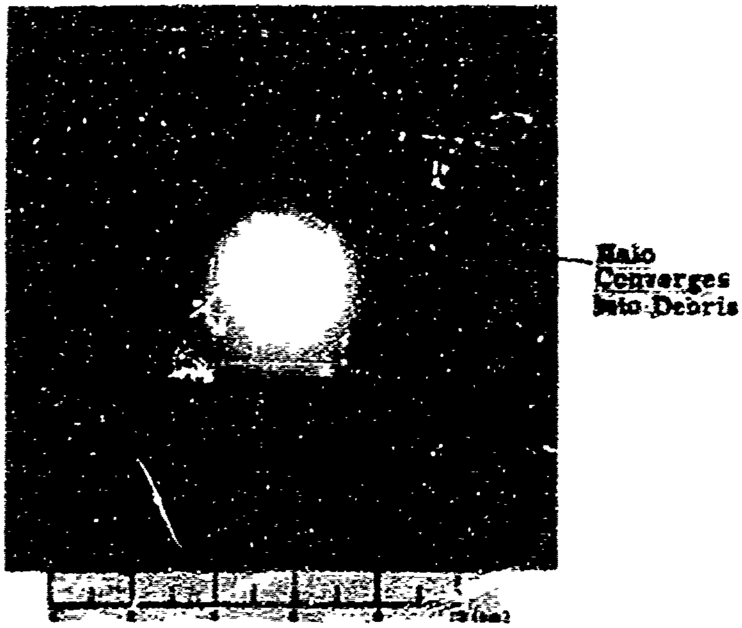


Figure 5.12 Fireball at 1.58 seconds, Station 830.02, 35-mm Fastax FF-2 camera, Shot Orange.

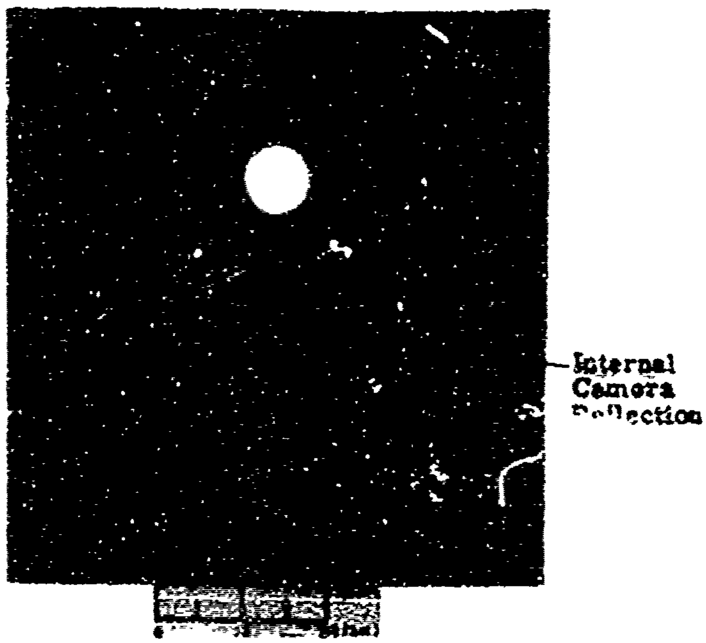


Figure 5.13 Fireball at 2.142 seconds, Station 830.02, 70-mm Maurer M-7 camera, Shot Orange.

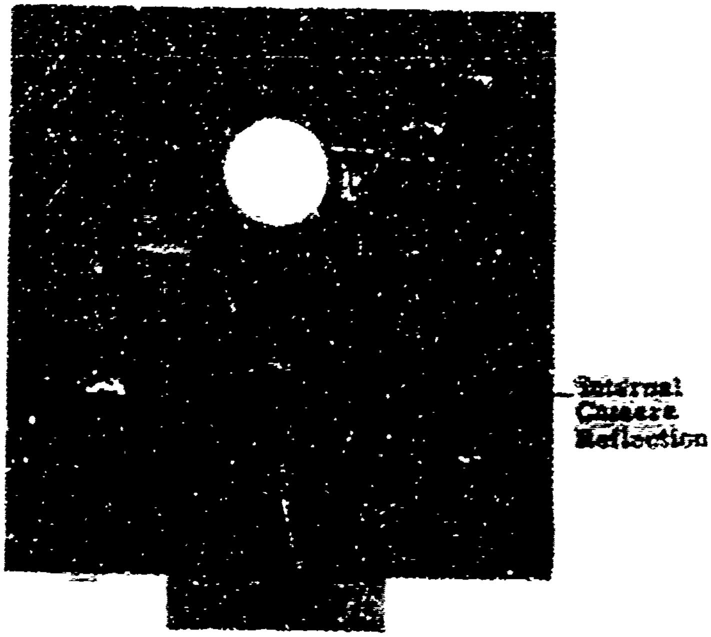


Figure 5.14 Fireball at 9.94 seconds, Station 830.02 70-mm Maurer M-7 camera, Shot Orange.

Figure 5.15 Fireball at 18.34 seconds, Station 830.02, 70-mm Maurer M-7 camera, Shot Orange

Figure 5.16 Fireball at 36.74 seconds, Station 830.02, 70-mm Maurer M-7 camera, Shot Orange

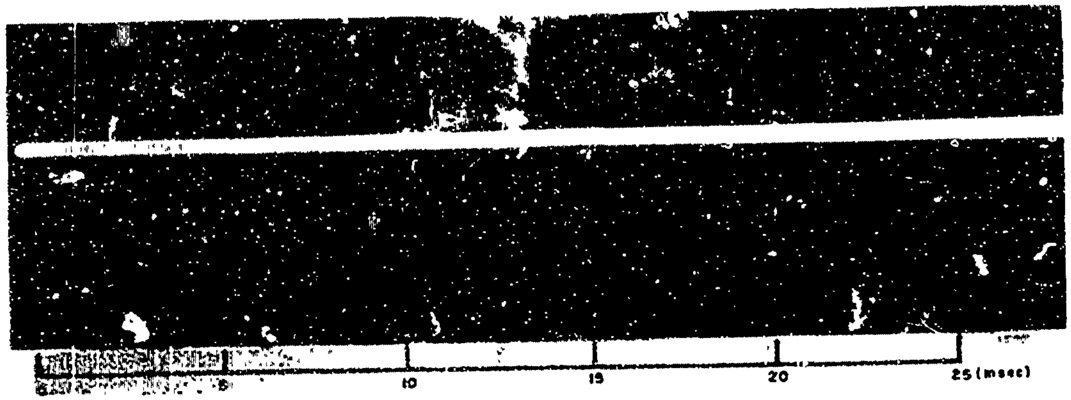


Figure 5.17 Streak record, 70-mm Streak-STR-6 (filter ND-1), Station 830.02 (horizontally mounted), Shot Orange.

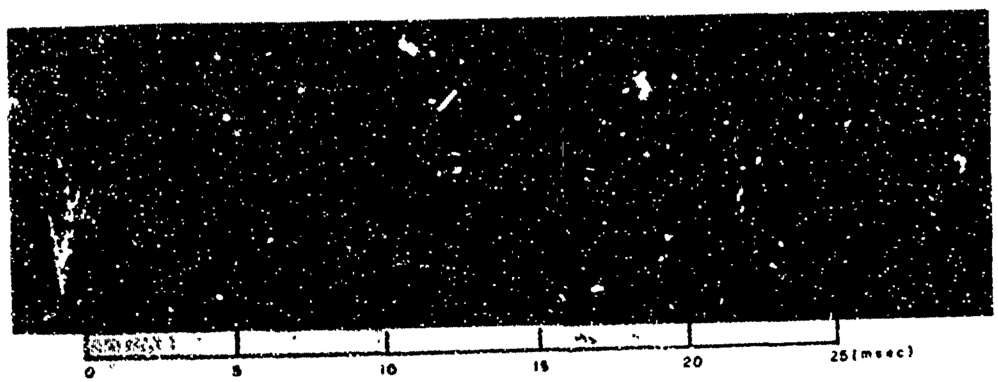


Figure 5.18 Streak record, 70-mm Streak-STR-4 (filter ND-4), Station 830.02 (vertically m . . Shot Orange.

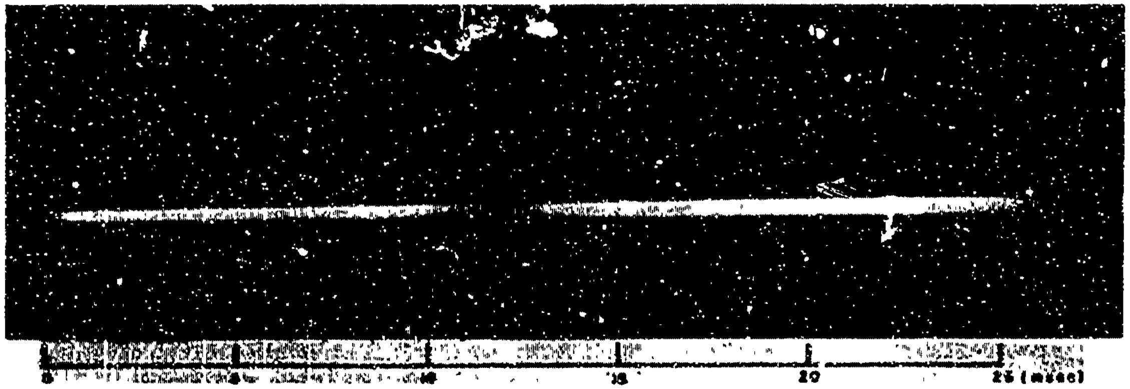


Figure 5.19 Streak record, 70-mm Streak-STR-2 (filter ND-3), Station 830.01 (horizontally mounted), Shot Orange.

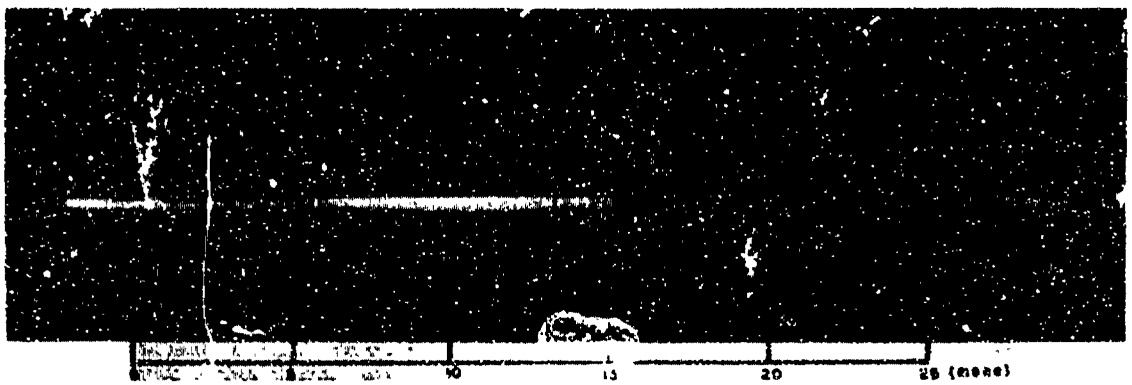


Figure 5.20 Streak record, 70-mm Streak-STR-5 (filter ND-3), Station 830.02 (horizontally mounted), Shot Orange.

Station 830.02 (horizontally mounted), Shot Orange.

Chapter 6

RECOMMENDATIONS

6.1 GENERAL

It is highly recommended that further photogrammetric analysis of the three Hardtack high-altitude detonations be pursued. Rate of rise of the burst phenomena, nature and dimensions of the aurora, and the light characteristics of the various phenomena are some of the areas that show promise of yielding useful data. The Hardtack high-altitude data and measurements from previous aerial tests should be evaluated in an attempt to determine scaling laws and to ascertain partition of energy data.

For future high-altitude tests, photographic coverage should be considerably expanded, with emphasis directed to obtaining better time resolution and additional significant phenomenological data by using more cameras and a wider variety of film types and lenses. The use of stabilized platforms for the airborne cameras and a fast exposure compensating system would contribute significantly to the improvement of detonation records. [illegible]s also highly recommended that extreme care be exercised in obtaining accurate air[illegible] data. It seems imperative to employ a tracking system whereby the cameras [illegible]e aimed at the missile continuously during its flight. Dependence on ground-cameras seems [illegible]uitful; at least three aircraft should be used, as outlined below.

6.2 DETONATION COVERAGE

In addition to the two aircraft stations and one ground station used for Teak and Orange, it is recommended that a third aircraft station be employed to permit a better coverage of events and a more detailed analysis of the spatial relationships of the various phenomena recorded. This third station would also serve as a backup to the other two.

At least two additional ground or shipboard stations are recommended for fireball coverage. One station should be located about 1,000 miles from the detonation, and the other at a convenient distance between the launch point photo station and the 1,000-mile station. For Shot Teak, EG&G had a station at Mt. Halcakala on the island of Maui, State of Hawaii. The purpose of the station was to make long-range light measurements of the high-altitude detonations. The Maui station was approximately 800 nautical miles from the Teak detonation. Excellent 35-mm color still films of Teak were recorded from that station, indicating the valuable technical potential of long-range photography of extremely high-altitude detonation phenomenology (Reference 5).

Extensive cloud cover over more than one ground station and/or any of the aircraft stations should be sufficient reason for shot postponement.

High-speed streak cameras capable of at least 0.1 μsec resolution are recommended for complete coverage of the first millisecond of fireball growth. High-speed framing cameras, capable of 25,000 frames/sec or more, should be used to obtain discrete pictures of fireball growth through the first 1.5 μsec. Rapatronic cameras should be

employed at one ground station for accurate early-time data, permitting precise determination of zero frame time on motion-picture film records. Rate-of-rise records should be obtained by aircraft cameras mounted in pairs, one aimed at the expected detonation point and the other aimed above it to record cloud rise beyond the field of view of the first camera.

Cameras with extra-wide fields of view are recommended for the recording of sky glow effects from the detonation.

6.3 AURORAL CONJUGATE POINT COVERAGE

Photographic coverage should be provided for the area of the expected auroral conjugate point. At least two airborne photo stations and two ground stations should be instrumented for recording auroral effects in the area. Coverage at the conjugate point would include timed photographs, to document aurora arrival time, configuration, and drift. In addition, these stations could provide long-range coverage of the sky glow from the detonation area.

6.4 FILM PROCESSING

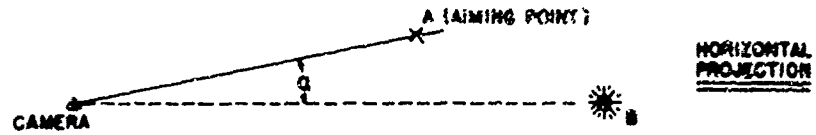
Facilities should be made available to provide adequate control of the processing of all films made. If such facilities cannot be provided in the field, then, in the interest of preserving irreplaceable photometric data, the films should be transported to a location with the necessary equipment to insure proper controlled processing of the records. Under no circumstances should hand processing techniques be employed.

Appendix A

SAMPLE CAMERA DATA AND FILM MEASUREMENTS

CAMERA DATA & CALCULATIONS

FILM NO. 50680	STATION NO. 830.01	TEST Yucca	CALCULATED BY: RS
CAMERA NO. STR #3	EQ. AP.		DATE: 3/19/59



A. $R^{0}/_{A} = CB_h \cos \alpha \cos \beta + (H_B - H_C) \sin \beta$

$\alpha =$ 5°08'	$\beta =$ 34° 38'	$H_B =$ 25511.29 m
$\cos \alpha =$ 0.995963	$\cos \beta =$ 0.822806	$H_C =$ 10973.93 m
$CB_h =$ 21497.90 m	$\sin \beta =$ 0.568322	$\Delta H =$ 14838.36 m
$CB_h \cos \alpha \cos \beta =$ 17617.19m	$\Delta H \sin \beta =$ 8432.97 m	$R^{0}/_{A} =$ $\boxed{260[illegible]6\ m}$

B. FOCAL LENGTH 149.06 mm (Lens Serial No. 729988)

C. MAGNIFICATION FACTOR (meters/in.) 4438.90

D. ZERO TIME CORRECTION

SECRET

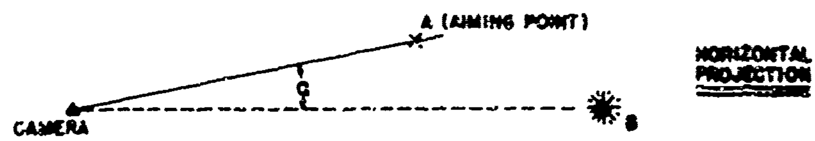
STREAK CALCULATION SHEET, FILM NUMBER 58

Shot Yucca, Streak Camera Number 3 Speed at zero ti , 18.23 ft/sec.

Time		Diameter		Time		Diameter	
microns (film)	msec	microns (film)	m	microns (film)	msec	microns (film)	meters
725	0.13	331	58.17	96,089	17.29	1,345	236.39
2,679	0.51	434	76.27	100,499	18.08	1,360	239 03
4 150	0.74	490	86.12	104,773	18.85	1,377	242.02
5,520	0.99	547	96.14	108,993	19.61	1,414	248.52
6,879	1.23	580	101.94	113,054	20.34	1,388	243.95
7,950	1.43	614	107 91	117,100	21.07	1,391	244.48
9,424	1.69	656	115 29	121,016	21.78	1,372	241.14
11,655	2.09	696	122.32	125,023	22.50	1,400	246.06
14,100	2.53	751	131.99	129,108	23.23	1,432	251 68
16,310	2.93	802	140.95	133,062	23.95	1,421	249.75
18,490	3.32	811	142.54	137,029	24.66	1,463	257.13
21,129	3.80	868	152.55	141,054	25.38	1,437	252.56
23,169	4.17	885	155.54	145,524	26.19	1,445	253.97
25,211	4.53	913	160 46	149,958	26.99	1,476	259.12
27,741	4.99	942	165.55	153,959	27.71	1,460	256.60
31,064	5.59	991	174.17	158,147	28.46	1,456	255.90
34,188	6.15	1,033	181.56	162,049	29.16	1,474	259.07
37,142	6.68	1,049	184.37	166,130	29.90	1,450	254.85
40,180	7.23	1,099	193.16	170,273	30.61	1,474	259.07
43,066	7.75	1,089	191.40	174,177	31.35	1,445	253.97
46,199	8.31	1,133	199.13	177,980	32.03	1,429	251.16
47,373	8 52	1,147	201.59	182,075	32.77	1,418	249 22
53,235	9 58	1,188	208.80	186,187	33.51	1,474	259.07
56,856	10 23	1,203	211.43	190,233	34.24	1,418	249.22
61,320	11 03	1,231	216.36	194,308	34.97	1,345	236.39
64,017	11 68	1,233	216 71	198,096	35.65	1,395	245.18
69,074	12.43	1,260	221.45	202,264	36.40	1,325	232.88
73,053	13.14	1,275	224.09	206,274	37.12	1,308	229.89
77,169	13 89	1,309	230.06	210,069	37 81	1,358	238.68
81,221	14 62	1,322	232.09	214,044	38.52	1,366	240.08
85,153	15 32	1,319	231.82	218,114	39.26	1,438	247.47
89,209	16 0	1,345	236.04	222,010	39.96	1,345	236.39
92,143	16.58	1,353	237 00	225,259	40.54	1,484	260 82

CAMERA DATA & CALCULATIONS

FILM NO. 34303	STATION NO. 830.01	TEST ORANGE	CALCULATED BY: RS
CAMERA NO. 35FFNo.1	EQ. AP.		DATE: 12/5/58



A. $R^{0}/_{A} = CB_h \cos e \cos \beta + (H_B - H_C) \sin \beta$

$e =$ 0°00'	$\beta =$ 12°11'	$H_B =$ 42980 m
$\cos e =$ 1.00000	$\cos \beta =$ 0.97748	$H_C =$ 9297 m
$CB_h =$ 132527m	$\sin \beta =$ 0.21106	$\Delta H =$ 33683m
$CB_h \cos e \cos \beta =$ 129542m	$\Delta H \sin \beta =$ 7108m	$R^{0}/_{A} =$ $\boxed{136650m}$

B. FOCAL LENGTH 101.36mm (Lens Serial No. B12678)

C. MAGNIFICATION FACTOR (meters/in.) 34310

D. ZERO TIME CORRECTION

DIAMETER MEASUREMENTS

SHOT ORANGE **FILM NO** 54303

Fr. No.	Mag.	R_1	R_2 in.	R_3	R_{avg}	FLEXOWRITER D_{avg} (m) xxx. xx	t (ms)
0000	18.33	0102	0112		107	1899.2	0.56
0001		0119	0125		122	2165.5	1.13
0002		0125	0130		129	2289.7	1.70
0003		0134	0136		135	2396.2	2.27
0004		0138	0140		139	2467.2	2.84
0005		0141	0144		143	2538.2	3.41
0008		0148	0153		151	2680.2	5.12
0010		0153	0156		155	2751.2	6.26
0012		0157	0160		159	2822.2	7.40
0014		0160	0164		162	2875.4	8.54
0016		0164	0167		166	2946.4	9.68
0018		0169	0171		170	3017.3	10.82
0020		0170	0172		171	3035.2	11.96
0025		0175	0179		177	3141.7	14.81
0030		0179	0182		181	3212.7	17.66
0035		0185	0185		187	3319.2	20.5
0040		0187	0193		190	3372.4	23.3
..		0194	0197		196	3478.8	26.6
0050		0195	0198		[illegible]	3486.7	29.01
0055		0199	0202		201	3567.7	31.91
0060		0201	0205		203	3603.2	34.91
0065		0203	0207		205	3638.7	37.61
0070		0207	0209		208	3692.0	40.42
0075		0209	0210		209	3709.7	43.31
0080		0208	0212		211	3745.2	46.16
0085		0210	0216		213	3780.7	49.01
0090		0211	0214		213	3780.7	51.91
0095		0214	0217		216	3833.9	54.71
0100		0216	0218		217	3851.7	57.56
0110		0218	0220		219	3897.2	63.16
0120		0219	0224		222	3940.4	66.76
0130		0224	0227		225	3993.7	74.36

READ BY R. C. S. J. C. **TYPED BY** ____

DATE 2/25/58 **DATE** ____

REMARKS:

DIAMETER MEASUREMENTS

SHOT ORANGE FILM NO 54303 (Page 2)

Fr. No.	Mag.	R_1	R_2 in	R_3	R_{avg}	FLEXOWRITER D_{avg} (m) xxx.xx	t (ms)
0140	19.33	0225	0230		228	4046.9	79.96
0150		0227	0231		229	4064.7	85.56
0160		0228	0234		231	4100.2	91.16
0170		0229	0237		233	4135.7	96.76
0180		0230	0240		235	4171.2	102.36
0190		0232	0242		237	4206.7	107.96
0200		0235	0245		240	4259.9	113.56
0210		0239	0247		243	4313.2	119.14
0220		0242	0246		244	4330.9	124.76
0230		0243	0248		246	4366.4	130.36
0240		0247	0250		249	4420.0	135.98
0250		0249	0254		252	4472.9	141.56
0260		0251	0252		252	4472.9	147.16
0270		0253	0256		255	4526.2	152.76
0280		0254	0259		257	4561.7	15[illegible]
0290		0357	0262		260	4614.9	16[illegible]
0300		0260	0265		263	4668.1	1[illegible] 56
[illegible]		0263	0265		264	4685.9	17[illegible]
[illegible]		0266	0268		267	4739.1	180.56
[illegible]		0270	0271		271	4810.1	186.06
[illegible]		0270	0274		272	4827.9	191.56
035[illegible]		0272	0277		275	4881.1	196.96
0360		0275	0280		278	4934.4	202.55
0370		0278	0281		280	4970.0	207.96
0380		0277	0286		282	5005.4	213.56
0390		0280	0287		284	5040.9	218.86
0400		0283	0288		286	5076.4	224.56
0410		0287	0290		289	5129.6	229.96
0420		0289	0292		291	5155.1	235.36
0430		0291	0294		293	5200.6	240.76
0440		0291	0295		293	5200.6	246.16
0450		0293	0299		295	[illegible]	251.56

READ BY R.C.S. J.C. TYPED BY

DATE 2/25/59 DATE

REMARKS:

DIAMETER MEASUREMENTS

SHOT ORANGE FILM NO 54303 (Page 3)

Fr. No.	Mag.	R_1	R_2 in.	R_3	R_{avg}	FLEXOWRITER D_{avg} (m) xxx.xx	FLEXOWRITER t (ms)
0460	19.33	0296	0298		297	5271.6	256.96
0470		0297	0301		299	5307.1	262.36
0480		0299	0302		301	5342.6	267.76
0490		0302	0303		303	5378.1	273.16
0500		030[illegible]	0307		305	5413.6	278.56
0510		0304	0309		307	5449.1	283.96
0530		0310	0313		312	5537.8	294.76
0550		0312	0315		314	5573.4	305.56
0575		0315	0321		318	5644.4	319.06
0600		0317	0324		321	5697.6	332.56
0625		0316	0327		323	5733.1	[illegible]
0650		0321	0330		325	5786.4	359.06
0675		0324	0333		329	5839.6	372.36
0700		0326	0335		331	5875.1	385.56
0725		0329	0336		333	5910.6	398.56
0750		0331	340		336	5963.8	411.56
0775		0333	344		33[illegible]	6017.[illegible]	424.56
[illegible]		0334	348		342	6070.4	437.56
[illegible]25		0336	352		344	6105.9	458.56
[illegible]		0338	354		346	6141.4	463.56
[illegible]		0340	356		348	6176.0	476.56
0900		0342	356		349	6194.6	489.56

READ BY R. C. S. J. C. TYPED BY

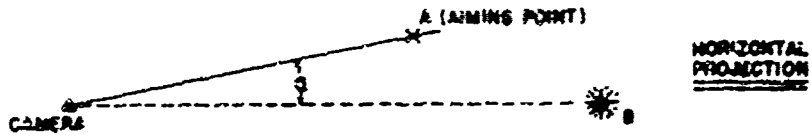
DATE 2/25/59 DATE

REMARKS:

SECRET

CAMERA DATA & CALCULATIONS

FILM NO. 54151	STATION NO. 230 01	TEST Teak	CALCULATED BY: RS
CAMERA NO. M-1	EQ. AP.		DATE: 12/3/58



A. $R^{B}/_{A} = CB_h \cos \varepsilon \cos \beta + (H_B - H_C) \sin \beta$

$\varepsilon =$ 0°00'	$\beta =$ 26°56'	$H_B =$ 76315 m
$\cos \varepsilon =$ 1.00000	$\cos \beta =$ 0.89153	$H_C =$ 9297 m
$CB_h =$ 118933	$\sin \beta =$ 0.45295	$\Delta H =$ 67018 m
$CB_h \cos \varepsilon \cos \beta =$ 106032 m	$\Delta H \sin \beta =$ 30356 m	$R^{B}/_{A} =$ $\boxed{13[illegible]8 \text{ m}}$

B. FOCAL LENGTH 34.77 mm (Lens Serial No. 3248077)

C. MAGNIFICATION FACTOR (meters/in.) 99632

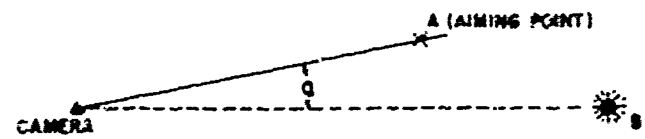
D. ZERO TIME CORRECTION

SECRET

TEAK Horizontal Diameter-Time Film No. 54151				NAME RCS-CJK		DATE 4/58	
Frame	D_i (mm)	D_1 (km)	D_3 (mm)	D_3 (km)	D_5 (mm)	D_5 (km)	Time (msec)
0	3.83	15.02	-	-	-	-	14.0
1	3.85	15.10	-	-	-	-	56.9
2	3.93	15.42	-	-	-	-	99.7
3	4.00	15.69	-	-	-	-	142.6
4	4.05	15.89	-	-	-	-	185.4
5	4.10	16.08	-	-	-	-	228.3
8	4.35	[illegible]	-	-	-	-	356.9
10	4.53	[illegible]	2.10	8.24	-	-	442.6
12	4.63	18.16	2.20	8.63	-	-	528.3
14	4.73	18.55	2.40	9.41	-	-	614.0
16	4.83	18.95	2.55	10.00	-	-	699.8
18	5.00	19.61	2.60	10.20	-	-	785.5
20	5.08	19.93	2.80	10.98	-	-	871.2
22	5.20	20.40	3.00	11.77	-	-	956.9
24	5.30	20.79	3.10	12.16	2.00	7.85	1042.6
26	5.40	21.18	3.20	12.55	2.10	8.24	1128.4
28	5.50	21.57	3.20	12.55	2.15	8.43	[illegible]
30	5.60	21.97	3.33	13.06	2.20	8.63	[illegible]
35	5.83	22.87	3.80	14.91	2.30	9.02	[illegible]
40	6.10	23.93	4.15	16.28	2.20	8.63	[illegible]
[illegible]	6.30	24.71	4.45	17.46	2.40	9.41	1942.7
[illegible]	6.50	25.50	4.70	18.44	2.58	10.12	2157.0
[illegible]	6.70	26.28	5.00	19.61	2.85	11.18	2371.3
60	6.85	26.87	5.30	20.79	2.95	11.57	2585.8
65	7.00	27.48	5.50	21.97	3.10	12.16	2800.0
70	6.90	27.07	5.90	23.14	3.25	12.75	3014.2
75	6.9	27.46	6.05	23.73	3.34	13.10	3228.5
80	7.1	27.85	6.20	24.32	3.48	13.65	3442.8
85	-	-	6.40	25.10	3.55	13.92	3657.1
90	-	-	6.60	25.89	3.70	14.51	3871.4
95	-	-	6.80	26.67	3.80	14.91	[illegible]
100	-	-	6.90	27.07	3.85	15.10	4300.0
105	-	-	6.90	27.07	3.95	15.49	4514.3
110	-	-	-	-	4.05	15.89	4728.6
115	-	-	-	-	4.10	16.08	4943.0
120	-	-	-	-	4.20	16.47	5157.2
125	-	-	-	-	4.30	16.87	5371.5

CAMERA DATA & CALCULATIONS

FILM NO. 54152	STATION NO. 330.01	TEST Teak	CALCULATED BY: RS
CAMERA NO. M-70 #4	EQ. AP.		DATE: 12/3/58



HORIZONTAL PROJECTION

A. $R^{0}/_{A} = CB_h \cos\epsilon \cos\beta + (H_B - H_C)\sin\beta$

$\epsilon =$ 0°00'	$\beta =$ 26°56'	$H_B =$ 76315 m
$\cos\epsilon =$ 1.00000	$\cos\beta =$ 0.89153	$H_C =$ 9297 m
$CB_h =$ 118933 m	$\sin\beta =$ 0.45295	$\Delta H =$ 67018 m
$CB_h \cos\epsilon \cos\beta =$ 106032 m	$\Delta H \sin\beta =$ 30356 m	$R^{0}/_{A} =$ $\boxed{136[illegible] \text{ m}}$

B. FOCAL LENGTH 79.58 mm (Lens Serial No. 4[illegible]3032)

C. MAGNIFICATION FACTOR (meters/in) 42531

D. ZERO TIME CORRECTION

TEAK Horizontal Diameter-Time Film No. 54152	NAME RCS-CJK	DATE 4/58

Frame	D_1 (mm)	D_1 (km)	D_3 (mm)	D_3 (km)	D_5 (mm)	D_5 (km)	Time (msec)
0	9.2	15.8	-	-	-	-	50
1	10.2	17.5	4.5	7.7	-	-	350
2	11.0	18.9	5.6	9.6	-	-	650
3	11.7	20.1	6.2	10.6	-	-	950
4	12.4	21.3	7.2	12.3	4.3	7.4	1250
5	13.2	22.6	8.2	14.1	4.5	7.7	1550
6	13.8	[illegible]	9.2	15.8	5.2	8.9	1850
7	14.5	24.9	10.0	17.1	5.6	9.6	2150
8	15.1	25.9	11.0	18.9	5.8	9.9	2450
9	15.5	26.7	11.8	20.2	6.1	10.5	2750
10	16.2	27.8	12.4	21.3	6.4	11.0	3050
11	17.0	29.1	13.2	22.6	6.7	11.5	3350
12	17.5	30.0	13.9	23.8	6.9	11.8	3650
13	18.2	31.2	14.6	25.0	7.3	12.5	3950
14	18.8	32.2	15.3	26.2	7.5	12.9	4250
15	18.3	32.9	15.9	27.3	7.7	13.2	4550
16	19.6	33.6	16.5	28.3	8.0	13.7	4850
17	-	-	16.8	[illegible]	8.4	14.4	515[illegible]
18	-	-	-	-	8.7	14.9	545[illegible]
19	-	-	-	-	9.0	15.4	575[illegible]
20	-	-	-	-	9.4	16.1	6050

TEAK	Vertical Diameter-Time Film No. 54152				NAME RCS		DATE 6/59
Frame (No.)	Time (ms)	D_0 (mm)	D_1 (mm)	D_2 (mm)	D_3 (mm)	D_4 (mm)	D_5 (mm)
0	50	10.7	10.4	10.3	2.1		
1	350	12.0	11.1	10.9	3.5		
2	650	13.0	11.9	11.6	4.5		
3	950		12.8	12.1	5.4		1.4
4	1250		13.6	12.7	6.3		2.2
5	1550		14.3		7.1		2.5
6	1850		14.9		8.0		2.8
7	2150				8.6		3.1
8	2450				9.6		3.5
9	2750				10.6		4.0
10	3050				11.5		4.2
11	3350				12.6	5.4	4.8
12	3650					6.4	5.0
13	3954					7.1	5.1
14	4250					7.9	5.1
15	4550					8.8	5.4
16	4850					9.6	5.6
17	5150						5.7
18	5450						6.0
19	5750						6.0
20	6050						6.3
21	6350						6.3
22	6650						6.3

SECRET

TEAK Vertical Diameter-Time Film No. 54152 NAME RCS DATE 6/59

Frame (No.)	Time (ms)	D_0 (km)	D_1 (km)	D_2 (km)	D_3 (km)	D_4 (km)	D_5 (km)
0	50	18.3	17.8	17.6	3.6		
1	350	20.6	19.0	18.7	6.0		
2	650	22.3	20.5	19.9	7.7		
3	950		21.9	20.7	9.3		2.4
4	1250		23.2	21.8	10.8		3.8
5	1530		24.5		12.2		4.3
6	1850		25.5		13.7		4.8
7	2150				14.7		5.3
8	2450				16.5		6.0
9	2750				18.2		6.9
10	3050				19.7		7.2
11	3350				21.6	9.3	8.2
12	3650					11.0	8.6
13	3950					12.2	8.7
14	4250					13.5	8.7
15	4550					15.1	9.3
16	4850					16.5	9.6
17	5150						9.8
18	5450						10.3
19	5750						10.3
20	6050						10.8
21	6350						10.8
22	6650						10.8

Appendix B

PHOTO DATA, SHOT YUCCA

PHOTO PLAN

STATION NO. E 30.01
STATION TYPE RB-36 15748
DISTANCE GZ 11.6 NM
DISTANCE OBJECT 35,692'

	STATION	G	DIFF.
N	426552	491,946	65394
E	337621	364,042	26421
Z	36,000'	84,680	48680

BRG 22°02'
TILT GZ ___
OBJ 34°38'

EVENT YUCCA
GZ STA. 42
DATE 2-19-58
POSTED ___

CAMERA NO.	CAMERA NOM. SPD.	CAMERA BACK POS.	LENS FOC. MM	LENS S/N	LENS FILTER	FIELD TARGET H/V	AIMING OBJECT	AIMING H	AIMING V	POWER VOLTS	POWER SHUT SPEED	POWER TIME ON/OFF	MARKER TYPE	MARKER S/N	DELAY	FILM	PURPOSE	REMARKS
1 70STR	20/sec	D-2	152	1150988	ND-5	37°30'	BURST	2°00'	34°38'	28DC	–	-25/+225	200	25	–	ME	8.3	
2 70STR		D-1		1829456	ND-4						–				–			
3 70STR		C-1		720988	ND-3						–				–			
1 35EE	2000	C-2	102	812878	ND-2 W-12	18.38 12.37				12DC	–				–			
M-1	24	B-4	35	3253077		55.84 4.29				28DC	30°	-15/+290	12½	25	–			
4 M-70	3½	B-1	80	4693032		56.56 56.63	CLOUD				1/500	-15/+100	–	–	–	FX		
3 KL-70	1/4	A-1	12.5	RM 139		57.42 43.03					1/25	-15/+30M	KLOCK	–	–	ME		
49 GSP	64	B-3	18.5	11243	–	46.17 32.90	DOC				133°	-5/+30	–	–	–	KDC		
156 GSP		B-2	25	C 32636	W-12	32.90 23.14	BURST				133°		.	–	–	ME		
181 GSP		VERTK	3.7	1.25	–	16.50	ZENITH	–	+90°		133°		–	–	–	ME		

REMARKS BACK AZIMUTH 202°

COPY WITH REV BY L.D.

SECRET

PHOTO LOADING CHART

STATION 830.01 RB-36 15748 EVENT YUCCA DATE 3-11-58

FILM					CAMERA			LENS		EXPOSURE			REMARKS
TYPE	EMULS. NO.	SIZE	HOLDER	PERF. NO.	NO.	RACK POS.	NOM. SPD.	FOC. MM	FILTER	APER	SHUTTER RHEO.	W/M²	
MF	1112-9-2	70-100	STR-MAG	50678	#7 70 STR	D-2	20/SEC	152	ND-5	f 8	-	3×10^{10}	
				50679	#2 70 STR	D-1			ND-4	f 8	-	3×10^{9}	
				50680	#3 70 STR	C-1			ND-3	f 8	-	3×10^{8}	
	1112-7-1	35-400	DAYLIGHT SPOOL	50681	#1 35 FF	C-2	2000	102	ND-2 W-12	f 8	-	1×10^{6}	δ 0.90
	1112-7-2	35-200	M-MAG	50682	M #1	B-4	24	35	W-12	f 20	30°	2×10^{4}	δ 0.90
FX	5240-626-2	70-50	MAURER MAG	50683	#4 M-70	B-1	3 1/3	80	W-12	f 4	1/500	40	
MF	1112-9-2	70-100	BEATTY MAG	50684	#3 C-70	A-1	1/4	105	W-12	f 5.6	1/25	40	
DAYLIGHT XDC	263362	15-50	U-MAG	50685	149 GSP	B-3	64	125	-	f 5.6	133°	40	
MF	1112-7-05			50686	176 GSP	B-2		25	W-12	f 2		40	δ 0.91
MF				50687	181 GSP	UPPER BLISTER		3.7	-	f 4.5		2×10^{2}	δ 0.92

DATE FILM LOADED 2-25-58 DATE CAMERA LOADED ________ DATE EXPOSED ________

REMARKS ________

COPY OF ORIGINAL

COPY OF ORIGINAL

SECRET

PHOTO PLAN

STATION NO. 83002
STATION TYPE BB-36 #15750
DISTANCE GZ 10.7 NM
DISTANCE OBJECT 22666'

STATION	GZ	DIFF.
N 498 14[illegible]	[illegible]	6801
E 277 370	[illegible]	64702
Z 37 000	[illegible]	47680

BRG 96°[illegible]
TILT
GZ
OBJ +34° 06'

EVENT YUCCA
GZ STA. 42
DATE 2-19-58
POSTED

CAMERA			LENS			FIELD	AIMING			POWER			MARKER		DELAY	FILM	PURPOSE	REMARKS
NO.	FROM SPD.	BACK POS.	FOC. MM	S/N	FILTER	TARGET H/V	OBJECT	H	V	VOLTS	SHUT SHDO.	TIME ON/OFF	TYPE	S/N				
4 70STR	20/SEC	C-1	152	2214341	ND-5	31 070	BURST	0° 00'	34° 06'	28DC	–	-25/+25	202	23	–	10F	2.3	
5 70STR		D-1		4974404	ND-4						–				–			
6 70STR		D-2		525660	ND-3						–				–			
2 35FF	2000	C-2	102	812888	ND-27 W-12	18 38 / 12 87				120DC	–				–			
M-2	24	B-4	35	1581060	W-12	55 84 / 41 39				28DC	30°	-15/+2M	125	22	–			
M-70	3 1/3	B-1	80	5003559		56 55 / 56 63	CLOUD				1/500	-15/+1M	–	–	–	FX		
4 KL-70	1/4	A-1	105	AM201		57 42 / 43 03					1/25	-15/+30M	CLOCK	–	–	MF		
60 GSP	64	B-3	18	11495	–	46 76 / 32 90	DOC				133°	-5/+30	–	–	–	KDC		
72 GSP		B-2	25	421117	W-12	32 90 / 23 14	BURST				133°		–	–	–	MF		
70 GSP		UPPER	37	[illegible]	–	165°	ZENITH	–	90°		133°		–	–	–	MF		

REMARKS BACK AZIMUTH 276°

COPY WITH REV B; LLD

PHOTO LOADING CHART

STATION 8J0 62 Y3-36 15750 EVENT Lecch DATE 3-11-58

FILM					CAMERA			LENS		EXPOSURE			REMARKS
TYPE	EMULS. NO.	SIZE	HOLDER	PERF. NO.	NO.	RACK POS.	NOM. SPD.	FOC. MM	FILTER	APER.	SHUTTER RHEO.	W/M²	
MF	1112-9-2	70-100	STR MAG	50700	#4 70 STR	C-1	20/SEC	152	ND-5	f 8	--	$3x10^{10}$	
				50699	#5 70 STR	D-1			ND-4			$3x10^9$	
				50701	#6 70 STR	D-2			ND-3		-	$3x10^8$	
	1112-7-1	35-400	DAYLIGHT REEL	50702	#2 35 FF	C 2	2000	102	ND-2 + W-12		-	$.x10^6$	8040
	1112 7-4	35-200	M-MAG	50703	M #2	B 4	24	35	W-12	f 20	30°	$2x10^7$	1092
FX	5240-636 2	70 SR	MAURER MAG	507.4	#7 M-70	B-1	3 ½	80		f 4	1/500	40	
MF	1112 4-2	70 100	BEAUTY MAG	50705	#4 CL-70	A-1	¼	105		f 56	1/25	40	
DAYLIGHT MDC	263368	16-50	V-MAG	50706	160 GSAP	B 3	64	185	--		133°	40	
MF	1112-7-05			50707	12 GSAP	B-2		25	W-12	f 2		40	8091
				50708	90 GSAP	UPPER BLISTER		37	--	f 45		$2x10^3$	8092

DATE FILM LOADED 7-22-58 DATE CAMERA LOADED ______ DATE EXPOSED ______

REMARKS ______

COPY OF ORIGINAL

SECRET

PHOTO PLAN

STATION NO. 943-USS BOXER

STATION TYPE SHIP

DISTANCE GZ ______

DISTANCE OBJECT ______

STATION			DIFF.	
N				GZ
E				OBJ
Z				

BRG ______ TILT ______

EVENT YUCCA

GZ STA. # 42

DATE 2-19-58

POSTED ______

CAMERA			LENS			FIELD TARGET	AIMING			POWER			MARKER		DELAY	FILM	PURPOSE	REMARKS
NO.	NOM SPD.	RACK POS.	FOC. MM	S/N	FILTER	H/V	OBJECT	H	V	VOLTS	SHUT BNEO.	TIME ON/OFF	TYPE	S/N				
#3 H-70	1/4	1	152	4397241	W-12	~67.0 / 67.0	BURST	0°-00'	RADAR MOUNT	115AC	1/25	-3 / +30M	–	–	–	MF	83	
#8 70STA	20/sec	2	304	58605	ND-2	~33.0 / 31.0				24DC	–	-2½ / +3	200	8	–	MF		
#104 GSP	32	3	40	RE 391	–	~53.0 / 39.0					133°	-5 / +1M	–	–	–	KDC-0		
#79 GSP	64	4	37	144	W-12	165°	ZENITH		90°			-5 / +30	–	–	–	MF		

REMARKS ______

COPY OF ORIGINAL

PHOTO LOADING CHART

STATION 943 USS BOXER EVENT YUCCA DATE 3-11-58

FILM					CAMERA			LENS		EXPOSURE			REMARKS
TYPE	EMULS. NO.	SIZE	HOLDER	PERF. NO.	NO.	RACK POS.	NOM. SPD.	FOC. MM	FILTER	APER	SHUTTER RHEO.	W/M²	
MF	1112-9-2	70-100	DAYLIGHT SPOOL	50670	#3 H-70	1	1/4	152	W-12	f5.6	1/4	50	
MF		7-100	STR MAG	50671	#8 70 STR	2	20/SEC	304	ND-2	f2	-	22×10⁷	
DAYLIGHT KDC	263368	16-50	V-MAG	50672	GSP-106	3	32	40	-	f8	133°	50	
MF	1112-07-05	16-50	V-MAG	50673	GSP-79	4	64	37	W-12	f2.5	133°	50	

DATE FILM LOADED 4-25-58 DATE CAMERA LOADED ______ DATE EXPOSED ______

REMARKS ______

COPY OF ORIGINAL

COPY OF ORIGINAL

SECRET

Appendix C

PHOTO DATA SHOT TEAK

STATION NO. 830.01

STATION TYPE RB36 1574R

DISTANCE GZ

DISTANCE OBJECT

PHOTO PLAN

	STATION	GZ	DIFF.
N	551268	[illegible]	248124
E	18432	194821	176439
Z	30500	250374	219874

BRG 153°7'21"

TILT

GZ 29°13'20"

OBJ

EVENT TEAK

GZ STA. HIGH ALTITUDE

DATE 7-21-58

POSTED

CAMERA			LENS			FIELD TARGET	AIMING			POWER			MARKER		DELAY	FILM	PURPOSE	REMARKS
NO	SHTM SPD	RACK POS.	FOC MM	S/N	FILTER	H/V	OBJECT	H	V	VOLTS	SHUT SYNC.	TIME ON/OFF	TYPE	S/N				
#7 70 STR	20/sec	C-1	152	1950998	ND-4	179 / 170	BURST	2°05'	[illegible]	28DC	–	-2½ / +2½	200	24	–	MF	8 3	
#3 70 STR		D-1		1827456	ND-3	179 / 170					–				–			
#3 70 STR		D-2		720488	ND-1	176 / 170					–				–			
#1 [illegible]FF	2000	[illegible]-2	102	B12828	W-12	175 / 78				120DC	–				–			
M-1	24	B-4	35	3348077		330 / 250				24DC	170°	-7½ / +2M	12½	25	–			
#4 M-[illegible]	3½	B-1	80	[illegible]693032		343 / 303	CLOUD				1/500	-15 / +1M	–	–	–	TX		
#5 [illegible]L 10	¼	A-1	105	RM1179	–	348 / 261					1/25	-15 / +30M	CLOCK	–	–	TX		
149 GSP	64	B-3	18.5	1125[illegible]	-	280 / 300	DOC				133°	-5 / +10	-	-	-	KDC		
176 GSP		B-2	25	K32[illegible]25	W-12	280 / 142	BURST						–	–	–	TX		
101 GSP		E-1	3.45	14[illegible]	-	165	ZENITH	-	90°				-	-	-	MF		

REMARKS THE CAMERA T[illegible]N ON TIMES ARE RE[illegible] TO BURST TIME.

COPY OF ORIGINAL

COPY OF ORIGINAL

SECRET

PHOTO L ADING CHART

STATION 830.01 RB36-15748 EVENT TEAK DATE 7-25-58

FILM					CAMERA			LENS		EXPOSURE			REMARKS
TYPE	EMULS. NO.	SIZE	HOLDER	PERF. NO.	NO.	RACK POS	NOM. SPD.	FOC MM	FILTER	APER	SHUTTER RHEO.	W/M²	
MF	1112-9-2	70-100	STR MAG	54147	#1 70-STR	C-1	20/sec	152	ND-4	f 16	—	10^8	
				54149	#2 70-STR	L-1			ND-3	f 6.3	·	10^6	
				54148	#3 70-STR	D-2			ND-1	f 6.3	—	10^4	
	1112-7-1	35-200	DAYLIGHT SPOOL MITCHELL	54150	#1 35 FF	C-2	2000	102	W-12	f 8	—	10^4	
	1112-7-2	35-200	MAG	54151	M #1	B-4	24	35		f 2.8	170°	20	
IX	5243 326-5	70-50	MAURER MAG	54152	#2 M-70	B-1	3 1/3	80		f 4	1/500	8	
IX	5243 236-4	70-100	BEATTY MAG	54153	#3 GC-70	A-1	1/4	105	—	f 4.5	1/25	0.1	
KOC	2049505	16-50	2-MAG	54154	149 GSP	B-3	64	18.5	—	f 2.8	133°	15	
IX	5241 326-11			54155	150 GSP	B-2		25	W-12	f 2.8	133°	1	
MF	1112-8-02			54150	151 GSP	E-1		3.45	—	f 2.8	133°	100	

DATE FILM LOADED ____ DATE CAMERA LOADED ____ DATE EXPOSED ____

REMARKS ____

COPY OF ORIGINAL

PHOTO PLAN

STATION NO. 830.02

STATION TYPE BB36-15750

DISTANCE GZ ______

DISTANCE OBJECT ______

	STATION	GZ	DIFF.
N	551269	203144	348124
E	377278	194871	182407
Z	30500	250374	219874

BRG 207°39'[illegible]

TILT GZ [illegible] OBJ ______

EVENT TEAK

GZ STA. HIGH ALTITUDE

DATE 7-21-58

POSTED ______

CAMERA			LENS			FIELD TARGET	AIMING			POWER			MARKER		DELAY	FILM	PUR-POSE	REMARKS
NO.	NOM SPD.	BACK POS.	FOC. MM	S/N	FILTER	H/V	OBJECT	H	V	VOLTS	SHUT RHEO.	TIME ON/OFF	TYPE	S/N				
#1 70STR	20/SEC	C-1	152	2214340	ND-4	192 / 126	BURST	0°00'	24°[illegible]	28DC	–	-2½ / +2½	200	23	–	MF	8.3	
#5 70STR		D-1		1374404	ND-3	192 / 128					–	-2½ / +2½			–			
#6 70STR		D-2		505400	ND-1	192 / 128					–	-2½ / +2½			–			
#2 35FF	2000	C-2	102	812888	W-12	333 / 38				12DC	–	-2½ / +2½			–			
M#2	24	B-4	35	AS81068		330 / 250				24DC	170°	[illegible]	12.5	22	–			
#7 M-76	3⅓	B-1	86	6023559		343 / 343	CLOUD				1/200	[illegible]	–	–	–	TX		
#4 CL-70	¼	A-1	105	BM231		348 / 281					1/25	[illegible]	CLOCK	–	–	TX		
109 GSP	64	B-3	18.5	L-118	–	280 / 200	DDG				135°	[illegible]	–	–	–	KDC		
12 GSP		B-2	25	48312	W-12	260 / 192	BURST					[illegible]	–	–	–	TX		
90 GSP		E-1	3.45	1916	–	105"	ZENITH		90°			[illegible]	–	–	–	MF		

REMARKS CAMERA TURN ON TIMES ARE RELATIVE TO BURST TIME

COPY OF ORIGINAL

SECRET

PHOTO LC DING CHART

STATION 8.0 02 AB 3-15720 EVENT 1F

DATE 7-25 51

FILM					CAMERA			LENS		EXPOSURE			REMARKS
TYPE	EMULS. NO.	SIZE	HOLDER	PERF. NO.	NO.	RACK POS.	NOM. SPD.	FOC. MM	FILTER	APER.	SHUTTER RHEO.	W/M²	
MF	1112-9 3	7½-100	STRENK MAG	54137	#4 70 STR	C 1	20' sec	152	ND-5	f 16.0	-	10^8	
				54138	#5 70 STR	D			ND-3	f 6.3	-	10^6	
				54139	#6 70 STR	D-2			ND-1	f 6.3	-	10^5	
	1112-7 1	35-400	DAYLIGHT SPOOL	54140	#2 35 FF	C-2	2000	103	W-12	f 8	-	10^4	
	1112-7 3	35-200	MITCHELL MAG	54141	M #2	B-4	24	35		f 2.8	170°	20	
TX	5243 326-5	70-50	MAURER MAG	54142	M-70	B-1	3⅓	80		f 4	1/1200	8	
TX	5243 236 4	70 100	BEATTY MAG	54143	#4 CL-70	A-1	¼	35		f 4.5	1/25	01	
KDC	264	16-50	U-MAG	54144	160 GSP	B-3	64	18.5		f 2.8	133°	15	
TX	5243 328-1			54145	2 GSP	B-2		25	W 12	f 2.8	133°		
MF	1112-8-02			54146	90 GSP	E-		3 45	—	f 2.8	133°	100	

DATE FILM LOADED ________ DATE CAMERA LOADED ________ DATE EXPOSED ________

REMARKS ________

COPY OF ORIGINAL

STATION I.D. 831 6X6 #1

STATION TYPE TRUCK

DISTANCE GZ

DISTANCE OBJECT

PHOTO PLAN

	STATION	GZ	DIFF.
N	200450	[illegible]	2694
E	200530	194871	5659
Z	~ 8	250374	~ 250370

BRG 295°29'26"

TILT GZ 88° 34'

OBJ

EVENT TEAK

GZ STA. HIGH ALTITUDE

DATE 7-21-58

POSTED

CAMERA			LENS			FIELD	AIMING			POWER			MARKER		DELAY	FILM	PURPOSE	REMARKS
NO.	NOM. SPD.	BACK POS.	FOC. MM	S/N	FILTER	TARGET H/V	OBJECT	H	V	VOLTS	SHUT. RHEO.	TIME ON/OFF	TYPE	S/N				
#7 70 STR	20/SEC	C-1	304	58618	ND-5	45/45	BURST	0°00'	82°18'	28DC	-	-2½/+2½	200	1	-	MF	8.3	ACTUAL DELAY
XB-7	4 in COIL	A-2	480	774693	-	35/35	BURST			115AC 24DC	BULB	-	FM	3	25 ms	EX		29.0 ms ACTUAL DELAY
XB-8	5 in COIL	A-3	480	773947	-	35/35	BURST			115AC 24DC	BULB	-	FM	3	50 ms	EX		52.5 ms
#7 SFF	2000	C-2	150	B49254	W-12	50/35	BURST			120DC	-	-2½/+2½	200	1	-	MF		
#4 H-70	3 1/3	B-1	150	4768175	W-12	14/125	CLOUD			115AC	1/75	-15/+2M	-	-	-	EX		
#10 H 70	1/4	A-1	38	840992	W-12	50/500	CLOUD			115AC	1/75	-15/+30M	-	-	-	TX		
113 GSP	64	A-1a	40	RM177	-	83/60	DOC			24DC	133°	-27/+30	-	-	-	KDC		
#4 35FF	2000	C-3	150	A90589	ND-4	50/35	BURST			120DC	-	-2½/+2	200	2	-	ECT 1229	18.1	
373 F-16	6000	E-1	53	C56175	-	560/375	SHADOW			180AC	-	-½/+½	200	8	-	MF		GOOSE UNIT
#8 F-16	6000	D-1	53	C5:465	ND-3	560/375	SHADOW			180AC	-	-½/+½	200	1	-	MF		GOOSE UNIT
83 GSP	64	TOP OF TRUCK	345	148	-	165°	ZENITH	-	90°	24DC	133°	-2½/+30	-	-	-	MF	8.3	

REMARKS ALL TURN ON TIMES ARE RELATIVE TO [illegible] T TIME

COPY OF ORIGINAL

COPY OF ORIGINAL

SECRET

PHOTO [illegible]ADING CHART

STATION 831 6x6 #1 EVENT TEAK DATE 7-24-58

FILM					CAMERA			LENS		EXPOSURE			REMARKS
TYPE	EMULS. NO.	SIZE	HOLDER	PERF. NO.	NO.	RACK POS	NOM. SPD.	FOC. MM	FILTER	APER.	SHUTTER RHEO.	W/M²	
ME	1112-9-2	70-100	STR-MAG	54126	#7 20-STR	C-1	20/sec	304	ND-5	f 6.8	-	5×10^7	
EX	6140 332 E10	2¼x3¼	RAP HOLDER	54127	XR-7	A-2	4 sec	480	-	f 11.0	BULB	2×10^7	
EX	↓	↓	↓	54128	XR-8	A-3	4 sec	480	-	f 11.0	BULB	2×10^7	
LIF	1112-7-1	35-400	DAYLIGHT SPOOL	54124	#3 35 FF	C-2	2000	152	W-12	f 8.0	-	10^4	
EX	5240-626-2	70-100		54130	#4 H-70	B-1	3½	152	W-12	f 5.6	1/75	2	
TX	5243-236-4	70-100		54131	#10 H-70	A-1	¼	38	W-12	f 4.5	1/75	0.1	
KDC	264605	16-50	U-MAG	54132	#11 GSP	[illegible]	64	40	..	f 2.8	133°	1.5	
ECT 1229	1229-393-1	35-500	DAYLIGHT SPOOL	54133	#4 35 FF	C-3	2000	152	ND-4	f 16.0	-	2×10^5	35 PER [illegible]
MS	1112-8-02	16-100	H.S. REEL	54134	#12 F-16	E-1	6000	5.3	-	f 8.0	-	2.5×10^5	7/25/58
TRI-X		16-100	H.S. REEL	54135	#8 F-16	[illegible]-1	6000	5.3	ND-3	f 8.0	-	2.5×10^7	
MF	111.-8-02	16-50	U-MAG	54136	#3 GSP	TOP OF TOWER	64	3.45	-	f 2.8	133°	100	

DATE FILM LOADED ______ DATE CAMERA LOADED ______ DATE EXPOSED ______

REMARKS 5×10^7 W/M² NOMINAL FOR ALL CAMERAS

COPY OF ORIGINAL

SECRET

Appendix D

PHOTO DATA, SHOT ORANGE

PHOTO PLAN

STATION NO. 830 01

STATION TYPE ZB 56 15 MB

DISTANCE GZ ______

DISTANCE OBJECT ______

	STATION	G	DIFF.
N	442 2 15	[illegible]	398 0[illegible]
E	[illegible]	[illegible]	114 39[illegible]
Z	305 [illegible]	[illegible]	[illegible]

BRG 136°[illegible]

TILT GZ 14°13'38"

OBJ ______

EVENT [illegible]

GZ STA. [illegible]

DATE [illegible]

POSTED ______

CAMERA NO.	CAMERA NOM SPD.	CAMERA RACK POS.	LENS FOC. MM	LENS S/N	LENS FILTER	FIELD TARGET H/V	AIMING OBJECT	AIMING H	AIMING V	POWER VOLTS	POWER SHUT RHEO.	POWER TIME ON/OFF	MARKER TYPE	MARKER S/N	DELAY	FILM	PURPOSE	REMARKS
#1 TOSR	20/sec	C-1	152	450998	ND-Y	105 / 105	BURST	0°00'	12°11'	25VDC	–	-2½ / +2½	200	24		MF	83	
#2 TOSR		D-1		10-9456	ND-3	105 / 125					–							
#3 TOSR		D-2		720988	ND-1	105 / 105					–							
#[illegible] 35mm	2000	C-2	162	312978	W-12	102 / [illegible]				120DC	–				–			
[illegible]	24	B-4	35	1248077		308 / 4.8				24DC	170°	-15 / +2M	12½	25				
#[illegible] M[illegible]	3[illegible]	B-1	8[illegible]	4643032		312 / 312	CLOUD				[illegible]	-15 / +1M			–	FX		
#3 [illegible]	[illegible]	A-1	[illegible]	RM179	–	317 / 237					[illegible]	-15 / +3M	[illegible]					
[illegible]	[illegible]	D-3	183	11243		250 / [illegible]	DOC				133°	-3 / +30	–		–	KOC		
[illegible]		3-2	25	[illegible]	N-12	151 / 129	BURST						–	–		FX		
[illegible]		[illegible]	375	[illegible]	–	105°	ZENITH		90°				–	–	–	MF		

REMARKS CAMERA TURN ON TIMES ARE RELATIVE TO [illegible] BURST TIME

COPY OF ORIGINAL

PHOTO LOADING CHART

STATION [illegible] EVENT [illegible] DATE [illegible]

FILM					CAMERA			LENS		EXPOSURE			REMARKS
TYPE	EMULS. NO.	SIZE	HOLDER	PERF. NO.	NO.	RACK POS.	NOM. SPD.	FOC. LEN	FILTER	APER	SHUTTER (SEC.)	W/M²	
MF	[illegible]	[illegible]	[illegible]	57300	[illegible]	[illegible]	20 [illegible]	15	ND-4	f 16		[illegible]	
				57301	[illegible]	[illegible]			ND-3	f 6.3		[illegible]	
				57302	[illegible]	[illegible]			ND 1			[illegible]	
	[illegible]	[illegible]		57303	[illegible]	[illegible]	2000	[illegible]	W 12	f 8.0		[illegible]	
	[illegible]	[illegible]	[illegible] MAG	57304	M#1	B-4	24	35		f 2.8	[illegible]	2.0	
[illegible]	[illegible]	[illegible]	[illegible] MAG	57305	[illegible]	[illegible]	[illegible]	80		f 4.0	1/500	8	
		[illegible]	[illegible] MAG	57306	[illegible]	A-1	[illegible]	.05		f 4.5	[illegible]	0.1	
[illegible]	[illegible]	[illegible]	[illegible] MAG	57307	[illegible]	B-2	64	[illegible]	-	f 2.8	[illegible]	[illegible]	
[illegible]	[illegible]			57308	[illegible]	B 2		25	W-12			1	
MF	[illegible]			57309	[illegible]	[illegible]		345	-			100	

DATE FILM LOADED ______ DATE CAMERA LOADED ______ DATE EXPOSED ______

REMARKS ______

[illegible]

[illegible]

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PHOTO PLAN

STATION NO. [illegible]
STATION TYPE [illegible]
DISTANCE GZ
DISTANCE OBJECT

	STATION	G.Z.	DIFF.	
N	[illegible]	[illegible]	[illegible]	GZ
E	[illegible]	[illegible]	[illegible]	OBJ
Z	[illegible]	[illegible]	[illegible]	

BRG [illegible]
TILT
GZ [illegible]
OBJ
EVENT [illegible]
GZ STA. [illegible]
DATE [illegible]
POSTED

CAMERA			LENS			FIELD TARGET	AIMING			POWER			MARKER		DELAY	FILM	PURPOSE	REMARKS
NO.	NOM. SPD.	BACK POS.	FOC. MM	S/N	FILTER	H/V	OBJECT	H	V	VOLTS	SHUT RHEO.	TIME ON/OFF	TYPE	S/N				
[illegible]	[illegible] sec	C-1	152	2217934	80-7	[illegible]	[illegible]	[illegible]	12°11'	2800		[illegible]	200	23		MF	83	
[illegible]		D-1		1574404	[illegible]													
[illegible]		D-2		545660	[illegible]										–			
[illegible]	2000	C-2	102	812881	W-12	102/71				1200	–				–			
M-2	24	D-4	35	958106		2.5/228				[illegible]	110°	[illegible]	12½	22	–			
M-20	3⅓	B-1	80	500335		[illegible]	[illegible]				1/300	[illegible]			–	[illegible]		
[illegible]	[illegible]	A-1	105	RM201		[illegible]					[illegible]	[illegible]	[illegible]	–				
G-2	64	B-3	153	11495	–	[illegible]	[illegible]				133°			–	–	[illegible]		
GSP		B-2	[illegible]	42311	W-12	[illegible]	[illegible]						–		–	[illegible]		
GSP		E-1	[illegible]	[illegible]		163°	ZENITH		90°				–	–	–	[illegible]		

REMARKS [illegible]

SECRET

PHOTO LOADING CHART

STATION B2002 RB-36 15-250 EVENT ORANGE DATE 8-2-58

FILM					CAMERA			LENS		EXPOSURE			REMARKS
TYPE	EMULS. NO.	SIZE	HOLDER	PERF. NO.	NO.	RACK POS.	NOM. SPD.	FOC. MM	FILTER	APER.	SHUTTER RHEO.	W/M²	
MF	1112 9-1	70-100	Daylight spool	54290	#4 70 CCP	--	20/sec	15	ND-4	f16		108	
				5429_	#5 Zeiss	D-1			ND-3	f6.3		106	
				54292	#6 Zeiss	D-2			ND-1			104	
	1112-7-1	35-200		54293	#2 35 C.C.	C-2	2000	102	W-12	f8.0	–	105	
	1112-7-2	35-200	MAG	54294	M #2	B-4	24	35		f2.8	1/100	20	
X	5243-326-5	70-50	Maurer MAG	54295	#7 M-20	B-1	3 1/3	80		f4.0	1/500	8	
		70 100	Beattie MAG	54296	#4 CL-20	A-1	1/4	105		f4.5	1/25	01	
KDC	264605	--50	U-MAG	54297	35	B-3	64	185	—	f2.8	133°	15	
TX	5243-328-13			54298	12 GSP	B-2		25	W-12			1	
MF	1118-11-2			54299	20 GSP	E-1		345	-			00	

DATE FILM LOADED ______ DATE CAMERA LOA[DED] ______ DATE EXPOSED ______

REMARKS ______

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PHOTO PLAN

STATION NO. [illegible]

STATION TYPE [illegible]

DISTANCE GZ

DISTANCE OBJECT

STATION	G.	DIFF.	TILT
N [illegible]	[illegible]	[illegible]	GZ [illegible]
E [illegible]	[illegible]	[illegible]	OBJ
Z [illegible]	[illegible]	[illegible]	

BRG [illegible]

EVENT [illegible]

GZ STA. [illegible]

DATE [illegible]

POSTED

CAMERA			LENS			FIELD TARGET	AIMING			POWER			MARKER		DELAY	PRIM	PURPOSE	REMARKS
NO.	NOM SPD.	RACK POS.	FOC. MM	S/N	FILTER	H/V	OBJECT	H	V	VOLTS	SHUT RHEO.	TIME ON/OFF	TYPE	S/N				
[illegible]	[illegible]	C 1	304	586?8	ND 3	25 / 25	BURST	0°00	[illegible]	25DC		[illegible]	[illegible]	1		MF	83	
[illegible]	[illegible]	A 2	480	774653		15 / 13				115AC / 24X?	3000		FM	3	2 ms	FX		
[illegible]	[illegible]	A 3	450	7739??		17 / 13					3000		FM	3	80 [illegible]	FX		
[illegible]	[illegible]	C 2	150	349251	[illegible]	[illegible]				1200		[illegible]	[illegible]	1		MF		
[illegible]	3?3	B	150	476179		[illegible]	CLOUD			115AC	15	[illegible]				FX		
[illegible]	[illegible]	H 1	38	540992		250 / 250					15	[illegible]	-			FX		
[illegible]	[illegible]	A 4	40	RM11?		45 / 30	DOC			24DC	330	[illegible]	-			[illegible]		
[illegible]	2000	C 3	35	450581	ND 3	28 / 20	BURST			2000	.	[illegible]	200	8		[illegible]	18	
[illegible]	6000	E 1	5.3	[illegible]		210 / 200	SHADOW			150AC				8		MF		[illegible]
[illegible]	6000	D 1	53	[illegible]	ND	300 / 200								1		FX		[illegible]
[illegible]	64	TOP [illegible] TRUCK	3.95	8		165°	ZENITH	-	90°	24DC	33°	[illegible]	-	-	-	MF	83	

REMARKS

[illegible]

SECRET

PHOTO LOADING CHART

STATION 83[illegible] EVENT [illegible] DATE 8-2-58

FILM					CAMERA			LENS		EXPOSURE			REMARKS
TYPE	EMULS. NO.	SIZE	HOLDER	PERF. NO.	NO.	RACK POS.	NOM. SPD.	FOC. MM	FILTER	APER.	SHUTTER REQ.	W/M²	
MI	1112 9-1	70-100	35R MAG	54279	#7 [illegible]	[illegible]	20/sec	304	ND-3	f6.3			
FX	1140 232010	2¼x3¼	KAP HOLDER	54280	XR 1	A-2	[illegible] cell	450		f11	BULB		
				54281	XR 8	A-3	[illegible] cell	450		f11	BULB		
MC	1112 [illegible]	35-[illegible]	DAYLIGHT SPOOL	54282	#3 [illegible]	C 2	2000	[illegible]	W 12	f8		10⁴	
FX	[illegible]	70 100		54283	#5 [illegible]	B 1	[illegible]	152		f5.6	[illegible]	2	
FX	[illegible]	70 100		54284	[illegible]	A-1	1/4	38		f4.5	1/25	[illegible]	
RD	[illegible]	16 50	V-MAG	54285	[illegible]	A-1a	64	110	-	f2.8	[illegible]	5	
[illegible]	[illegible]	[illegible] 400	DAYLIGHT SPOOL	54286	#4 [illegible]	C 2	2000	152	ND-3	[illegible]			
MF	1112-8 [illegible]	16 100	HS REEL	54287	#12 E-16	E 1	6000	53	-	f5	-		
FX		16 [illegible]		54288	#8 E-16	D-1	6000	5.3	ND-1	f8			
MF	1112-8 [illegible]	16 [illegible]	V-MAG	54289	83 [illegible]	TOP OF TRUCK	64	375	-	f2.8	[illegible]	100	

DATE FILM LOADED ______ DATE CAMERA LOADED ______ DATE EXPOSED ______

REMARKS ______

[illegible]

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REFERENCES

1. "Technical Summary of Military Effects, Programs 1 - 9 (U)", Operation Teapot, WT - 1153, February 1960, Office of the Chief of Staff for Weapons Effects Tests, Headquarters Field Command, Defense Atomic Support Agency, Sandia Base, Albuquerque, New Mexico. Secret Restricted Data.

2. F. H. Shelton, "Phenomenology of a High-Altitude Atomic Explosion", SC - 3363 (TR), April 1954, Sandia Corporation, Albuquerque, New Mexico, Secret Restricted Data.

3. Rocket Panel Atmosphere, Physical Review, 1952, Vol 88, Page 1027.

4. Glenn P. Elliott and others, "Operation of Missile Carrier for Very-High-Altitude Nuclear Detonations (U)", Project 9.3a, Operation Hardtack, WT - 1657, May 1959, U.S. Army Ballistic Missile Agency, Redstone Arsenal, Alabama, Secret Restricted Data.

5. J. C. Champeny, "Very Long Range Light Measurements", Contract AF 29(600) - 36126, Report B - 1863, Edgerton, Germeshausen & Grier, Inc., Boston, Massachusetts, Secret Restricted Data.

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78- 16 Chief, Bureau of Naval Weapons, Navy Department, Washington 25, D.C. ATTN: RR12

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105 Commander, Air Force Ballistic Missile Div. HQ. ARDC, Air Force Unit Post Office, Los Angeles 45, Calif. ATTN: WDSOT

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108-112 Commander, Air Force Special Weapons Center, Kirtland AFB, Albuquerque, N. Mex. ATTN: Tech. Info. & Intel. Div.

113-114 Director, Air University Library, Maxwell AFB, Ala.

115 Commander, Lowry Technical Training Center (TW), Lowry AFB, Denver, Colorado.

116 Commandant, School of Aviation Medicine, USAF Aerospace Medical Center (ATC), Brooks AFB, Tex. ATTN: Col. G. L. Hekhuis

117-120 Commander, Wright Air Development Center, Wright-Patterson AFB, Dayton, Ohio. ATTN: WCACT (For WCOSI)

121-122 Director, USAF Project RAND, VIA: USAF Liaison Office, The RAND Corp., 1700 Main St., Santa Monica, Calif.

123 Chief, Ballistic Missile Early Warning Project Office, L. G. Hanscom AFB, Bedford, Mass. ATTN: Col. Leo V. Skinner, USAF

124 Commander, Air Technical Intelligence Center, USAF, Wright-Patterson AFB, Ohio. ATTN: AFCIN-4B1a, Library

[illegible] [illegible] Chief of Staff, Intelligence, HQ. USAFE, APO [illegible], New York, N.Y. ATTN: Directorate of Air Targets

126 Commander-in-Chief, Pacific Air Forces, APO 953, San Francisco, Calif. ATTN: PFCIE-MB, Base Recovery

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133 Commander, Field Command, DASA, Sandia Base, Albuquerque, N. Mex.

134 Commander, Field Command, DASA, Sandia Base, Albuquerque, N. Mex. ATTN: FCTG

135-136 Commander, Field Command, DASA, Sandia Base, Albuquerque, N. Mex. ATTN: FCWT

137 Commander-in-Chief, Strategic Air Command, Offutt AFB, Neb. ATTN: OAWS

138 U.S. Documents Officer, Office of the United States National Military Representative - SHAPE, APO 55, New York, N.Y.

139 SAC(SUP3.1), Offutt AFB, Nebr.

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SUBJECT: Declassification of AD-360632L (WT-1649).

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AD-360632L (WT-1649)

for Naomi L. Fields
ARDITH JARRETT
Chief, Technical Support

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